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WHITEHORSE COPPER BELT
A Simplified Technical History

By

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MacKay Falkiner and Associates

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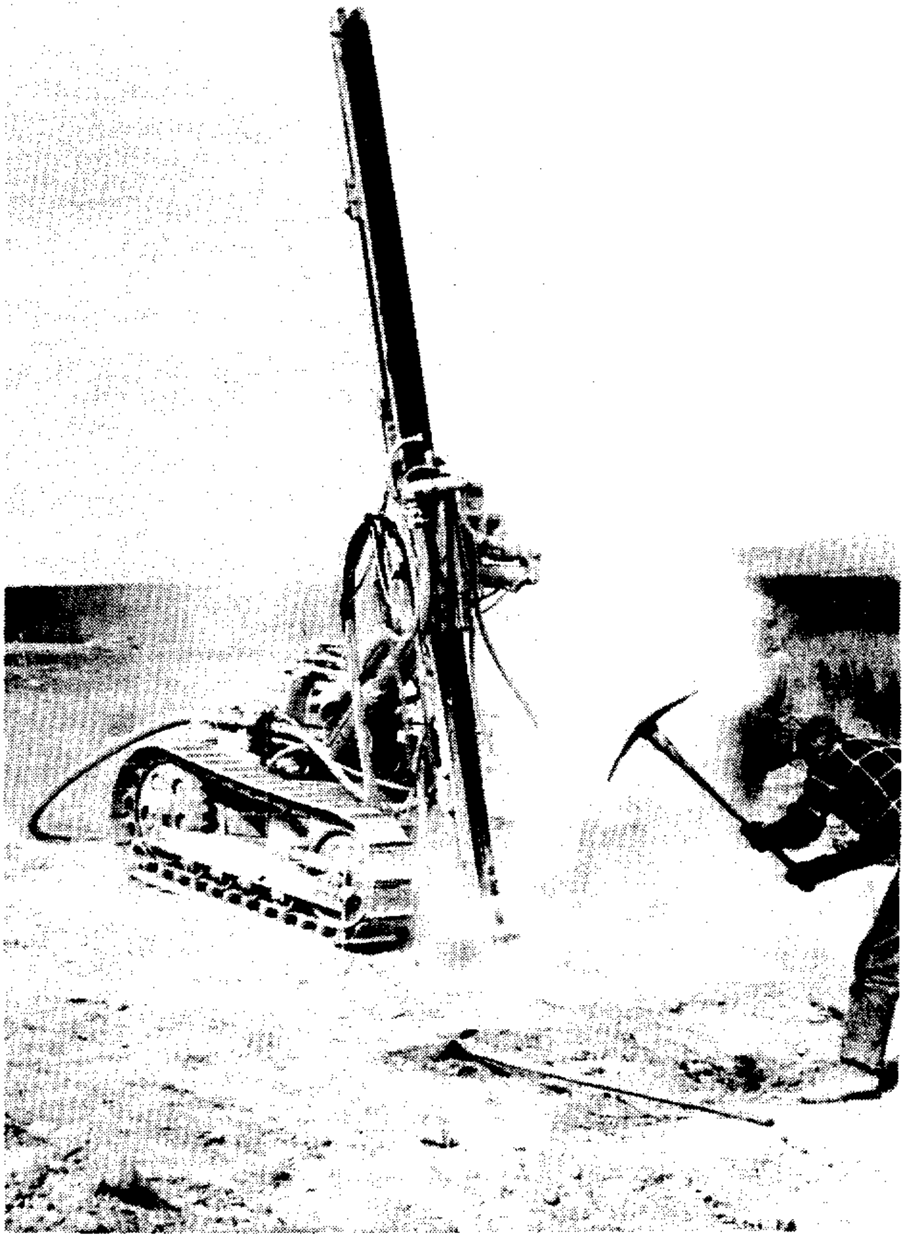
WHITEHORSE COPPER BELT
A SIMPLIFIED TECHNICAL HISTORY



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Front Cover: The old and the new - turn of the century and "modern" techniques used on the Whitehorse Copper Belt.

(Whitehorse Star Collection, Yukon Archives)

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1. INTRODUCTION

The Whitehorse Copper Belt is a northwest-trending chain of copper-bearing **skarn** deposits, located four kilometres west of the City of Whitehorse. The belt extends parallel to the Alaska Highway for thirty kilometres, from the Crestview subdivision to the junction of the Alaska Highway and the South Klondike Highway (Figure 1).

From the time Jack McIntyre staked the Copper King in 1898 the belt has been vigourously prospected and mined for its valuable copper, gold and silver metals.

This report presents the geology of the major ore deposits in the Whitehorse Copper Belt and discusses exploration, mining techniques and metal production. It is intended to provide background information of a technical nature to aid in the development of historical presentations for secondary school students.

A companion paper by Helen Dobrowolsky and Rob Ingram will discuss the general history of the Whitehorse Copper Belt and its impact on infrastructure development.

2. GEOLOGY OF WHITEHORSE COPPER BELT

2.1 Geologic History

The Whitehorse Copper Belt contains a variety of **sedimentary** and **igneous** rocks. These rocks were deposited and deformed over a 225 million year period.

Approximately 225 million years ago, large volcanoes erupted great quantities of lava and ash, which created a range of volcanic mountains. Erosion of these newly formed mountains resulted in large volumes of sediment rich in copper, iron, gold and silver, being carried by rivers down to an ancient sea.

Upon reaching the ocean, the river currents gradually lost their ability to transport the sediments. The larger particles settled out first and were deposited as sand on beaches and deltas along the coast. These deposits of sand were buried by more sediment and eventually formed layers of sandstone.

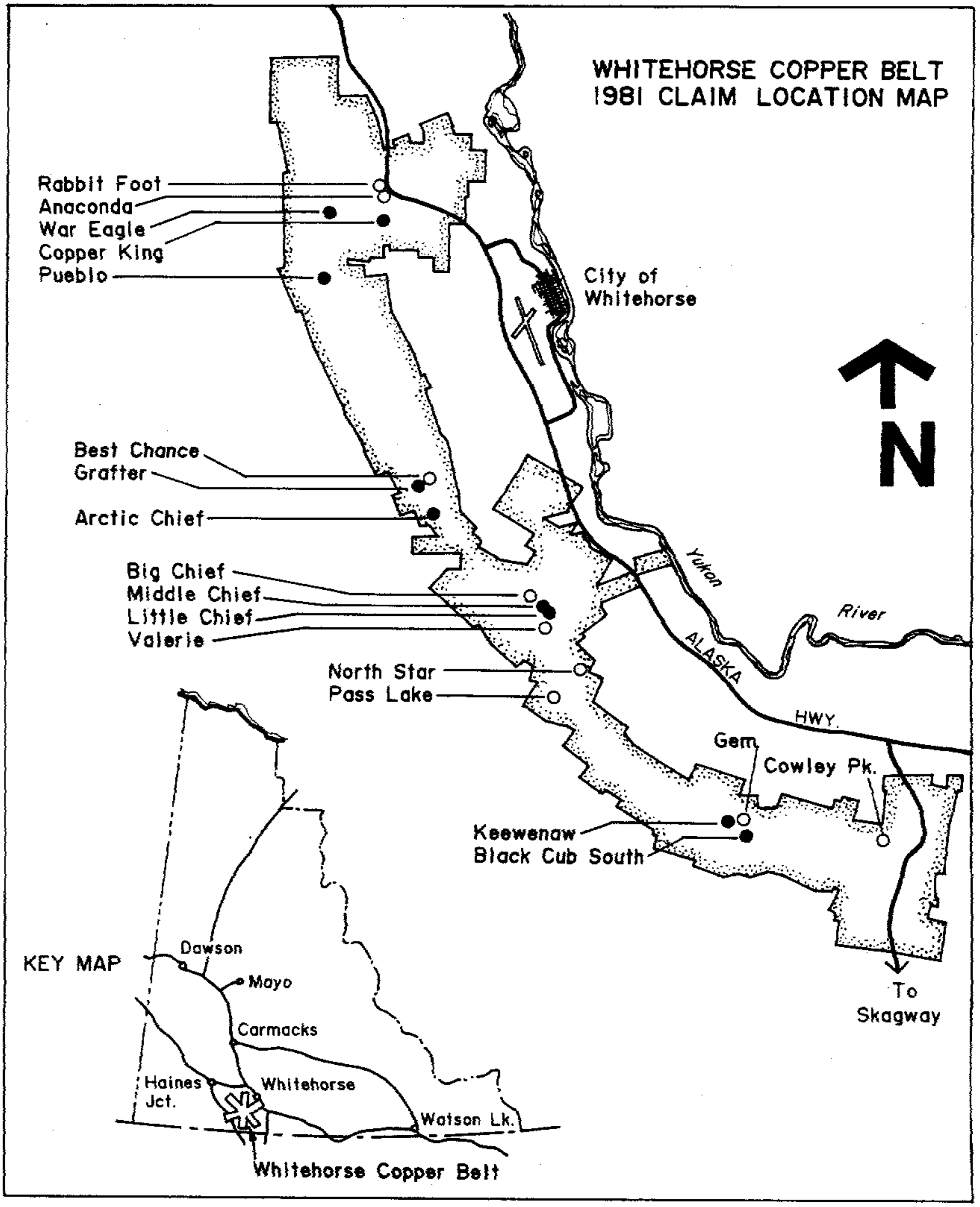

FIGURE 1 : Map of Whitehorse Copper Belt showing the largest Copper deposits. The main producers are shown as black circles. (adapted from Tenney, 1981)

Medium and finer grained material was carried further out into the sea and formed layers of silt and mud, which eventually became **siltstone** and **shale**.

When volcanism stopped, coral reefs flourished in the warm shallow waters off the ancient coast. The skeletal remains of these corals slowly accumulated over 10-15 million years and formed thick patches of limestone. Coral reefs, broken by crashing ocean waves, mixed with incoming sediment from rivers and formed limy siltstone. The continual accumulation of these sediments and limestone over 60 million years produced a seven kilometre thick sequence of sedimentary rocks in the Whitehorse Trough basin (Figure 2).

Due to a collision between two of the great plates that form the Earth's crust these sedimentary rocks were folded and faulted approximately 180-120 million years ago .

Approximately 110 million years ago, large bodies of molten **magma** intruded the folded sedimentary rocks. The hot, rising magma heated and melted its way towards the surface, ingesting great volumes of sedimentary and volcanic rocks. It also fractured, wedged open, and penetrated existing cracks and other weaknesses in the rock. When the magma eventually cooled it created a large granitic body called a **pluton** (Figure 3).

Water from the magma and ground water from the sedimentary rocks was driven by the heat from the slowly cooling magma and circulated through the rock around the pluton. This water was rich in metals such as copper, iron, silver and gold which was obtained from the ingested sedimentary and volcanic rocks. These hot and corrosive circulating fluids dissolved more metals out of the siltstone and sandstone and carried them away in the solution (Morrison, 1981).

When this solution came in contact with limestone, a chemical reaction occurred. The limestone, which is made up of minerals composed of calcium and magnesium carbonate, was dissolved and much of the carbonate was driven off as carbon dioxide gas. The calcium and magnesium mixed with the silica and metal-rich circulating solutions and formed the skarn deposits.

Erosion then brought the skarn deposits to the surface of the earth.

A small volcanic event approximately 2 million years ago deposited flows of Miles Canyon

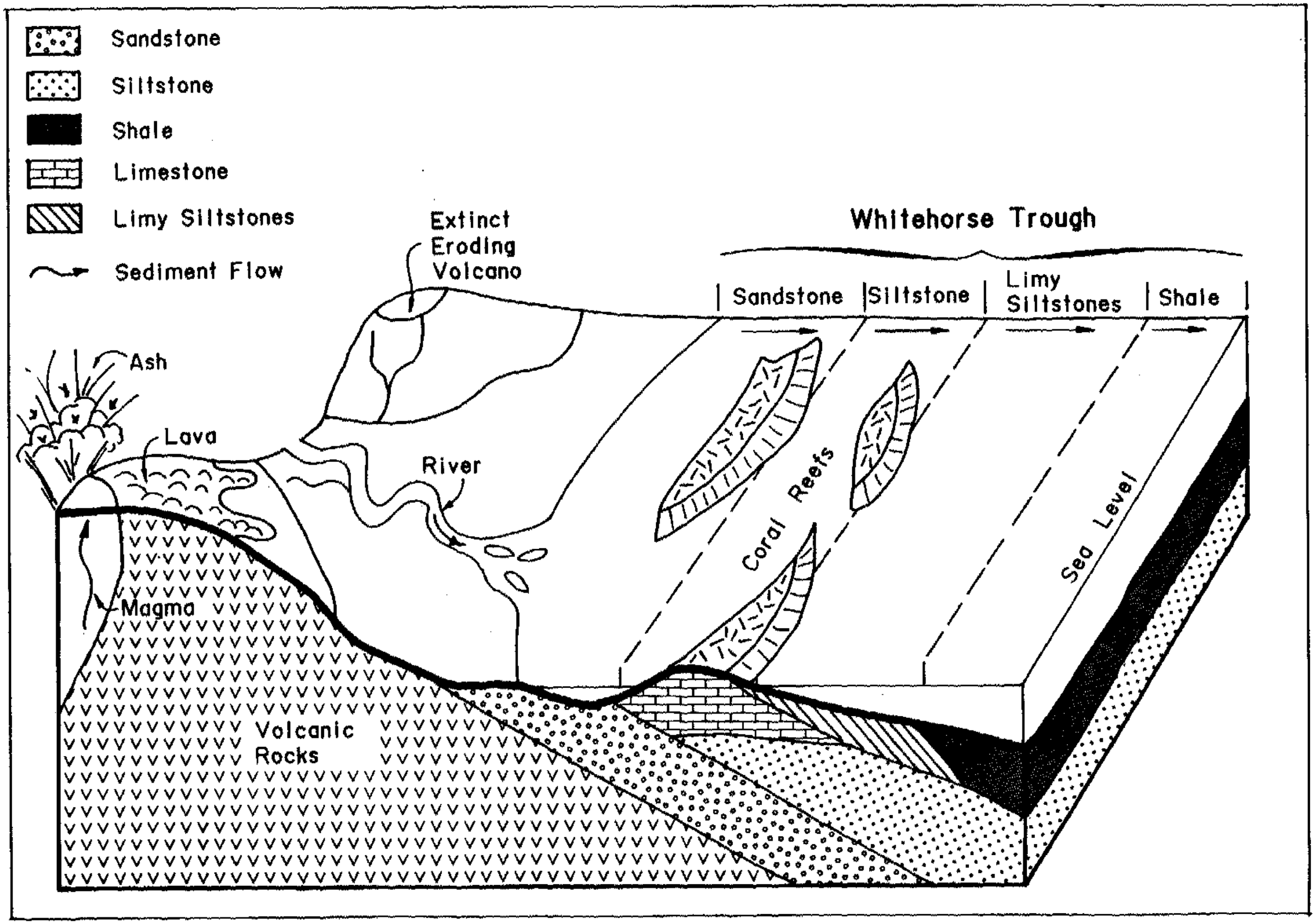

FIGURE 2 : Deposition of Sediments in the Whitehorse Trough about 225 million years ago.

basalt along the east side of the Copper Belt. Cracking in the basalt flows as they cooled created the distinctive columns that are seen in Miles Canyon and on the north side of the ski hill road, one kilometre west of the Alaska Highway. The intrusive dikes that fed the basalt flows are exposed in the Keewenaw open pit.

Further erosion has exposed the skarn deposits with their associated sedimentary rocks as **embayments** in, or as disjointed rafts completely surrounded by (**roof pendants**), the pluton (Figure 4).

2.2 Skarn Composition

The copper skarn deposits of the Whitehorse Copper Belt can be divided into two distinct types: **iron-rich** skarns and **calc-silicate** skarns.

Iron-rich skarns are characterized by an abundance of the minerals serpentine and magnetite. Serpentine is used as a rock name that refers to masses of the mineral antigorite ($Mg_3Si_2O_5(OH)_4$). This rock is commonly mottled light to dark green with a greasy wax-like appearance. Magnetite (Fe_3O_4) is a dark black mineral which occurs in granular masses. Magnetite is characterized by its strong magnetic response.

Calc-silicate skarns are rich in garnet and diopside. Garnet ($Ca_3Fe_2SiO_{12}$) occurs as light to dark brown masses in which individual crystals are hard to distinguish. Diopside ($CaMgSi_2O_6$) is light green and occurs in fine to medium grained masses. Other minerals that are common in calc-silicate skarns include wollastonite, tremolite, actinolite, quartz and feldspar.

In both types of skarns, copper occurs primarily as the sulphide minerals, chalcopyrite and bornite. Chalcopyrite ($CuFeS_2$) is a brass yellow sulphide mineral composed of one part copper, one part iron and two parts sulpher. It can be mistaken for pyrite (FeS_2) or gold. Bornite (Cu_5FeS_4) is brownish bronze in colour but is usually tarnished to purple and blue, resulting in its slang name of peacock ore. Bornite is more common in the iron-rich skarns (Hart and Pelletier, 1989). Both of these sulphide minerals occur either as disseminated grains or as denser masses. Minor amounts of gold and silver

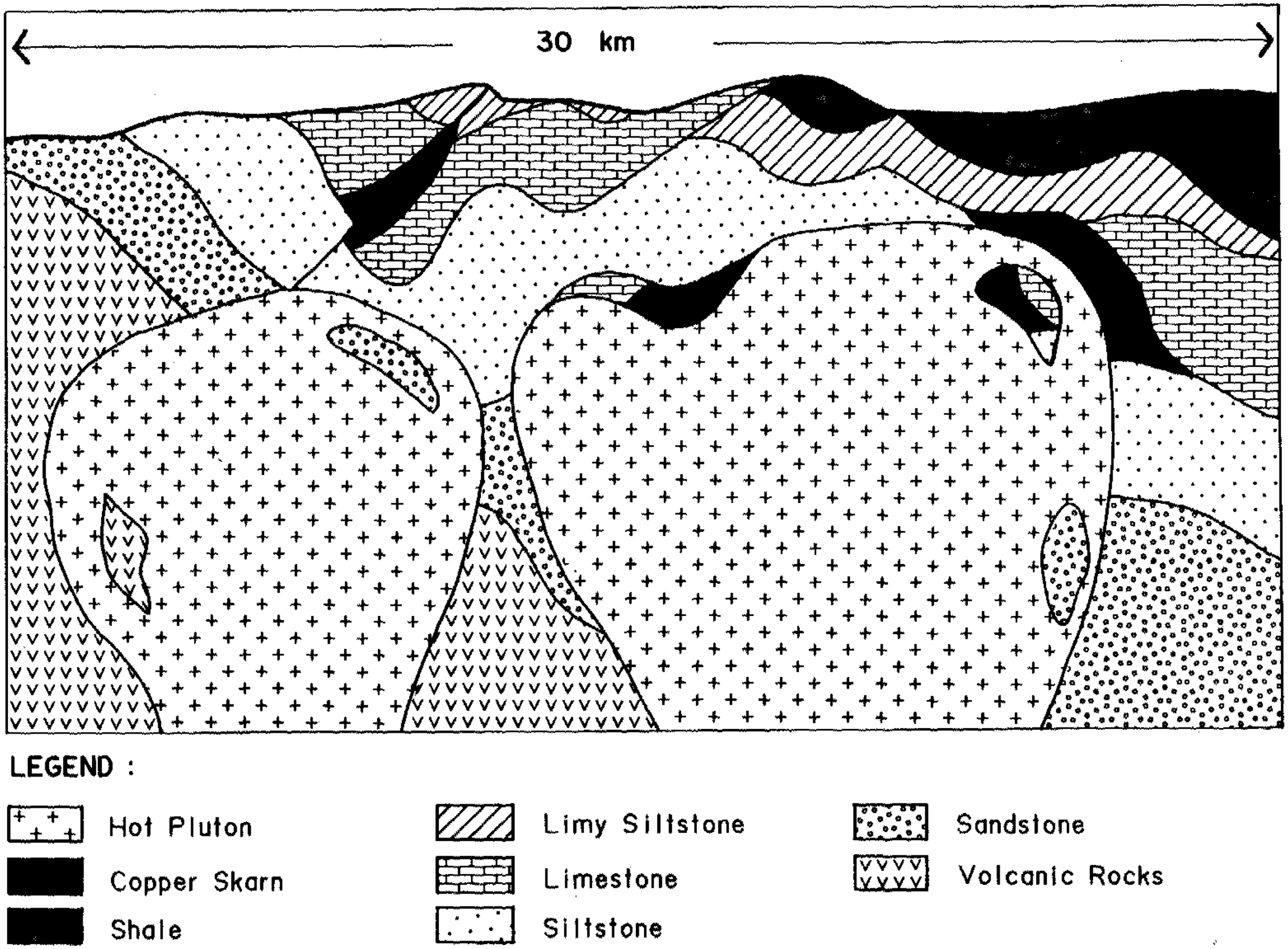

FIGURE 3 : Plutons Invade the Folded Sedimentary Rocks of the Whitehorse Trough Forming Copper Skarns. (approx. 100 million years ago)

also occur in these skarns and are generally associated with the chalcopyrite and bornite. The metal molybdenum occurs as molybdenite (MoS_2) and is restricted to the calc-silicate skarns (Tenney, 1981).

The calc-silicate skarns are generally very hard, dense and competent, providing very good ground conditions for mining. This reduces the danger of cave-ins and the need for timbering to support the underground workings.

The magnetite skarns, on the other hand, are broken due to faults and as a result are unstable, providing very poor ground conditions for mining. These deposits are much more dangerous and required extensive **timbering** and ground support (Morrison, 1981).

3. EARLY EXPLORATION AND MINING (1897-1929)

Stampeders enroute to the Klondike in 1896 and 1897 were the first to discover the copper skarn deposits of the Whitehorse Copper Belt. The influx of thousands of would-be miners along the trail to Dawson City left a swath of closely prospected land and was responsible for the discoveries of most of the presently known deposits on the Copper Belt (McConnell, 1909).

Surface weathering of copper-bearing ore minerals creates the brilliantly-coloured green and blue minerals, malachite ($Cu_2CO_3(OH)$) and azurite ($Cu_3(CO_3)_2(OH)_2$). Prospecting rock outcrops for these minerals proved to be very successful in locating the copper-bearing skarns (MacLean, 1914).

Early exploration of the copper **showings** consisted mostly of surface prospecting and underground tunnelling. Once a showing was discovered the **overburden** would be stripped off to determine the orientation of the deposit. When the surface expression was known, exploration **shafts** (vertical tunnels), **adits** (horizontal tunnels) or **declines** (inclined tunnels) were driven to test the extent of mineralization at depth (Figure 5).

The type of opening made depended on whether the mineralization occurred in a flat area or on a hill. If possible, an adit would be driven into the deposit and then **drifting** was done along the

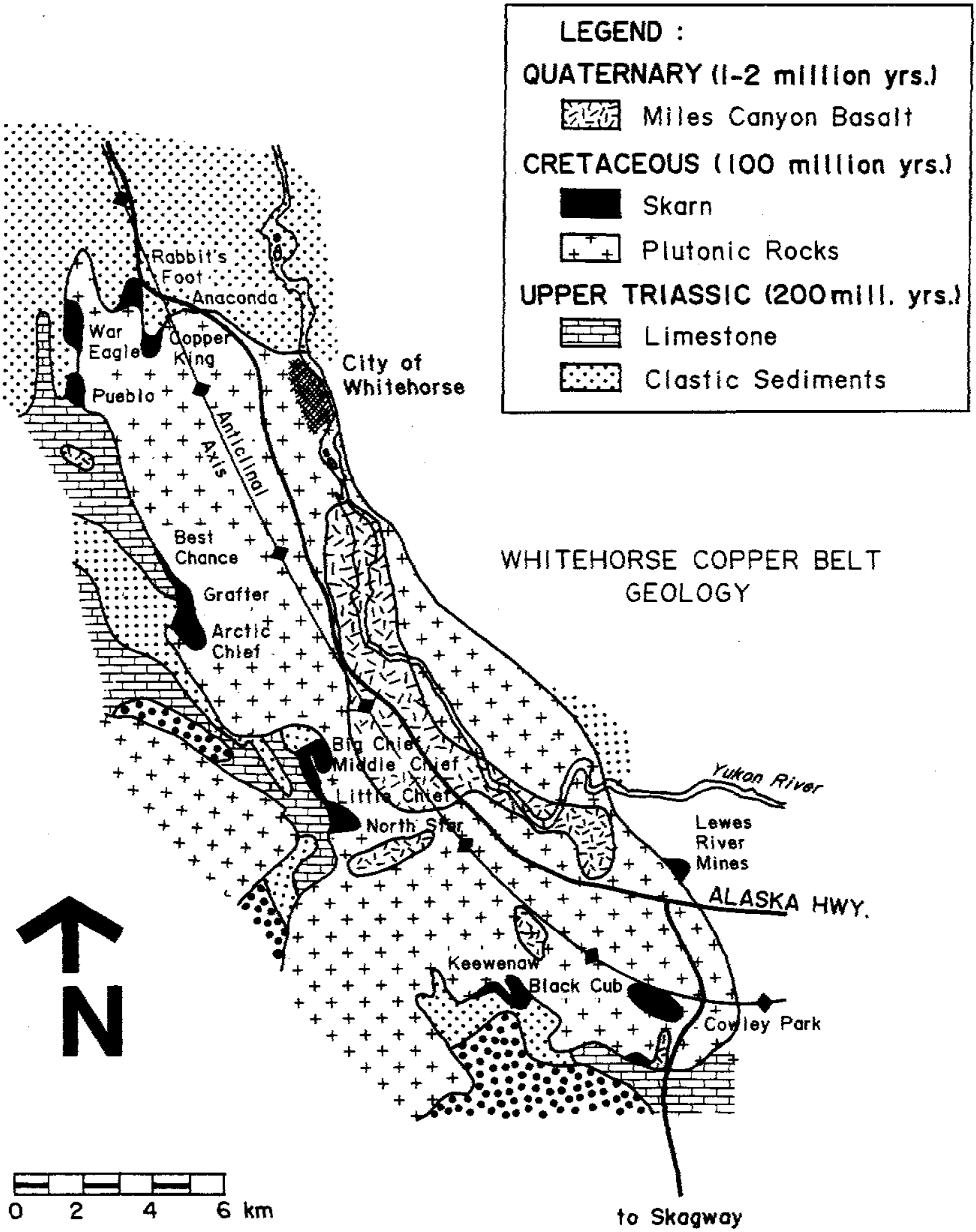

FIGURE 4 : Regional Geology of the Whitehorse Copper Belt (modified from Kindle, 1964 and Tenney, 1981)

deposit. If an adit or decline was not practical a shaft would be sunk from the surface for up to 100 feet, then a drift would be driven along the deposit. Perpendicular to the drifts **crosscuts** were driven through the deposit to test the width and grade of the mineralization.

The line between exploration and mining was imprecise. If a **high grade** zone was encountered in an exploration crosscut it would be mined out, creating a large open room called a **stope**.

The size of the stope was directly related to the size of the high grade zone and the competency of the ground; the more competent the ground the larger the possible stope. A zone in the Grafter, for example, was stoped out nearly to surface from a crosscut 50 feet (15 m) below the surface (McConnell, 1909).

Much of the early underground mining was done using labour-intensive methods. Adits, shafts, drifts and crosscuts were built by drilling several short holes into the rock face, loading them with dyna-

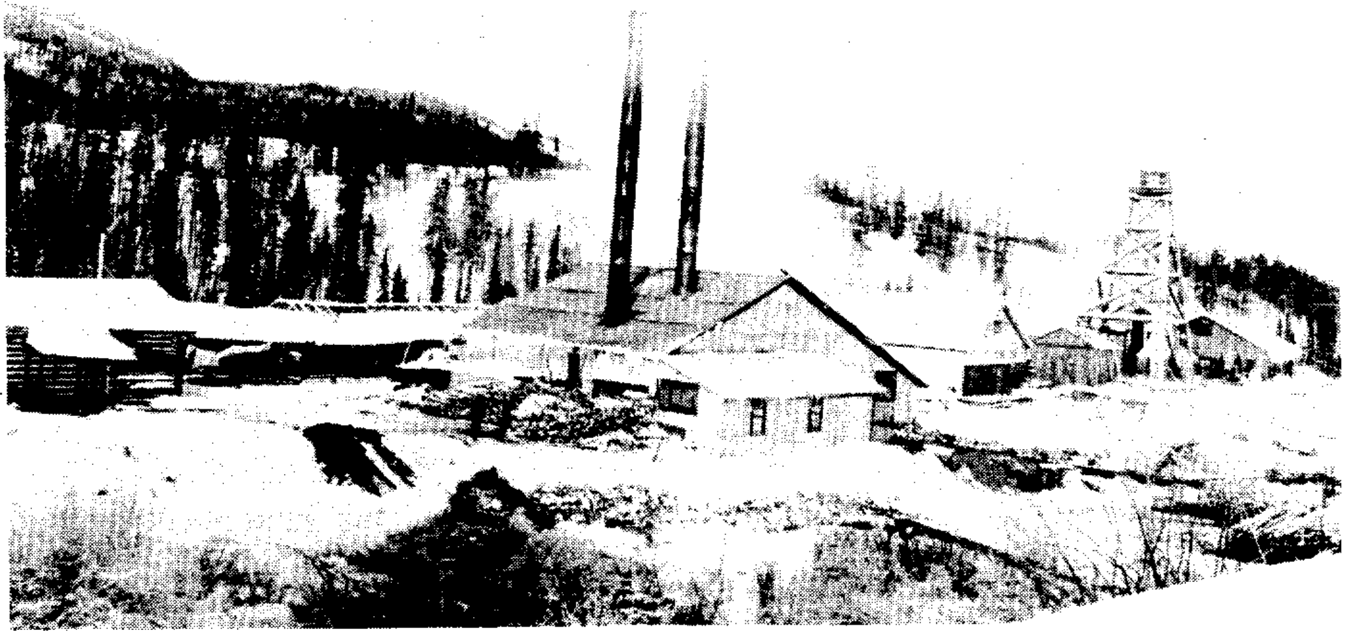

Photo 1: *Pueblo Mine site, 1912. Building in the centre housed the wood-fired boilers which provided power to operate the hoist and to run pumps. Headframe is on the right side of the photo.*

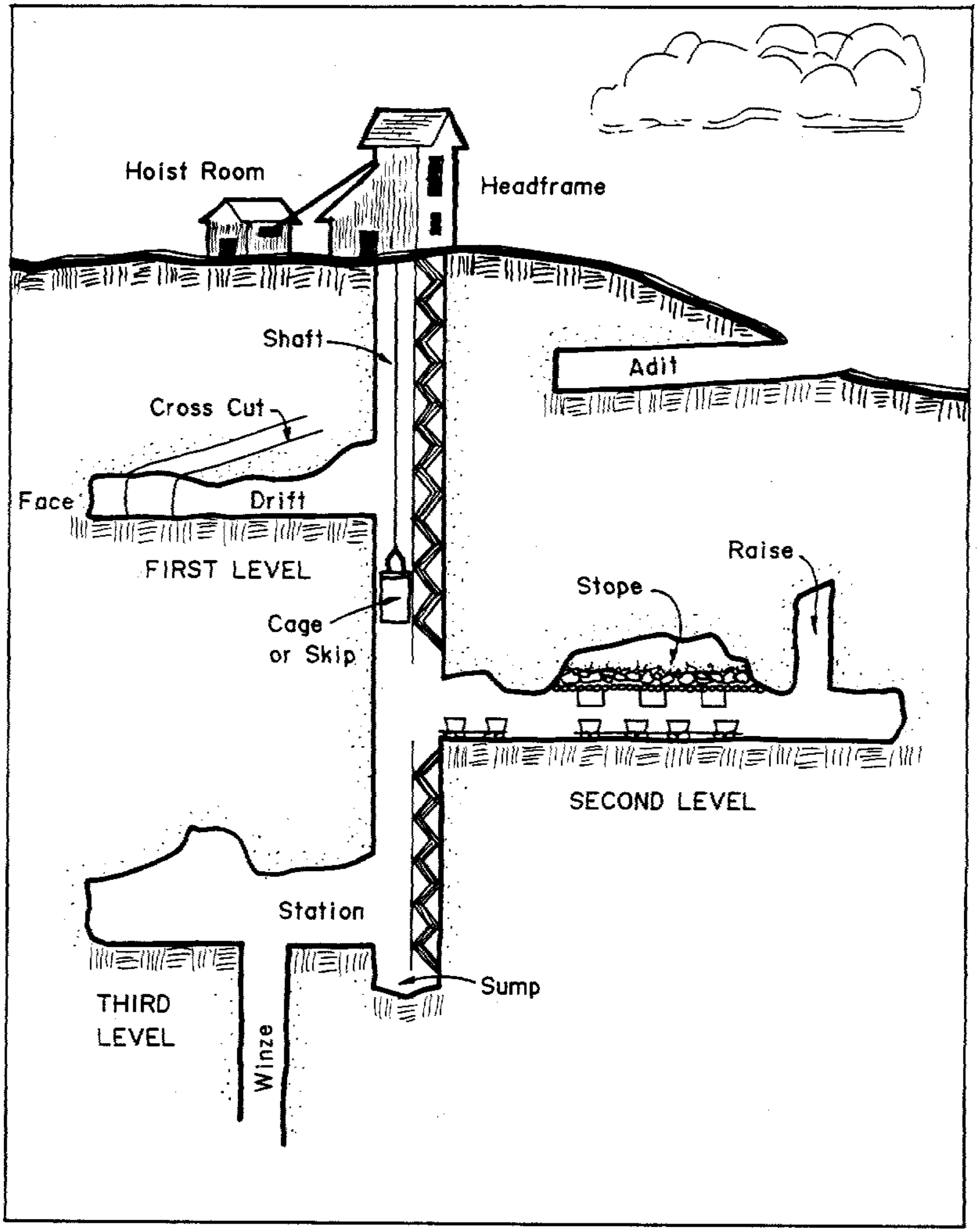

FIGURE 5 : Diagram Showing Typical Workings in Early Underground Mines on the Whitehorse Copper Belt. (adapted from Barnes, 1986)

mite and blasting out the surrounding rock. The broken rock, called **muck**, was put into ore carts on rails and pushed by hand down the crosscuts and drifts to the shaft or, if there was an adit, directly to surface.

At the shaft the muck was loaded into huge buckets and hoisted to surface by hand, mule or steam power, depending on the sophistication of the operation. A headframe was normally constructed to contain the hoisting equipment.

In the small operations holes for blasting were drilled with **handsteels** (long narrow shafts of steel) which were driven into the rock with hammers. The larger mines, including the Copper King, the Pueblo and the Grafter were equipped with large steam boilers which operated hoists, pumps, and drove large air compressors. (Pare, 1908). Compressed air was piped into the underground workings where it was used in mechanized rock drills at the mining face.

Squared logs called **timbers** were used where necessary to reinforce the underground workings.

Shaft sinking was the single most expensive part of mine development, costing up to $40/foot

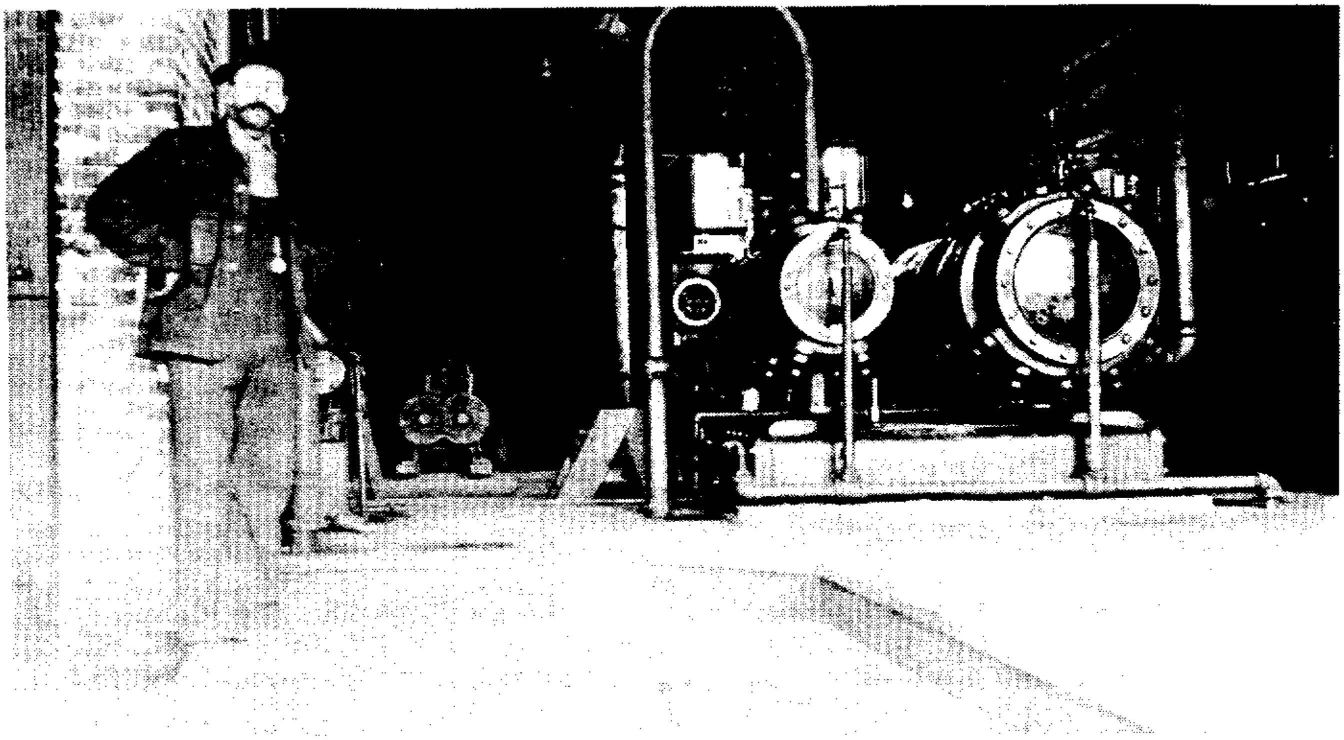

Photo 2: *Air compressors at the Pueblo Mine, 1912.*

($130/m) if timbered, while drifting in rock that did not require timbering cost $10/foot ($33/m). This was at a time when an underground miner was paid $4/day (Pare, 1908).

Drifts and crosscuts at the same depth were grouped together and called **level workings.** They were given a number corresponding to the depth in feet below the surface that they occurred (i.e.: the 50 foot level workings).

The miners faced a continual battle with water seeping into the workings. In 1917, the Pueblo had to pump 600 gallons (2700 litres) of water per minute from its 500 foot (152 m) level (Gaffin, 1980). This surplus of water was at least partly responsible for the major cave-in which occurred in the mine that year.

Water was also a problem if the mine had to be abandoned for any length of time. The water would seep into the workings, then freeze. It was both difficult and dangerous to thaw the ice, since it had to be done with open fires in the enclosed underground space. Deadly build-up of gases from the fires was responsible for a number of deaths. (For details see the companion paper by Dobrowolsky and Ingram).

Where high grade mineralization occurred at surface it was often mined in a surface pit called a **glory hole**. Mine cars on tracks would be run into the pit to remove the ore and waste after blasting

Although most of the early exploration was done by underground development, steam-driven **diamond drills** leased from the Territorial Government were common by 1914 (MacLean, 1914). A hollow pipe with a diamond-impregnated bit on the end was used to drill holes through the showings at depth, recovering a **core** of rock from underground. Analyzing samples of the core for copper provided valuable information on whether to pursue more costly development work. This allowed for better planning and made it easier for companies to raise money based on the value of drill-indicated **ore reserves**.

From 1920-1945 little exploration activity occurred in the Copper Belt. The Richmond-Yukon company drilled sporadically in the belt but little additional interest was shown until 1946-47 when Noranda Exploration became involved (Tenney, 1981).

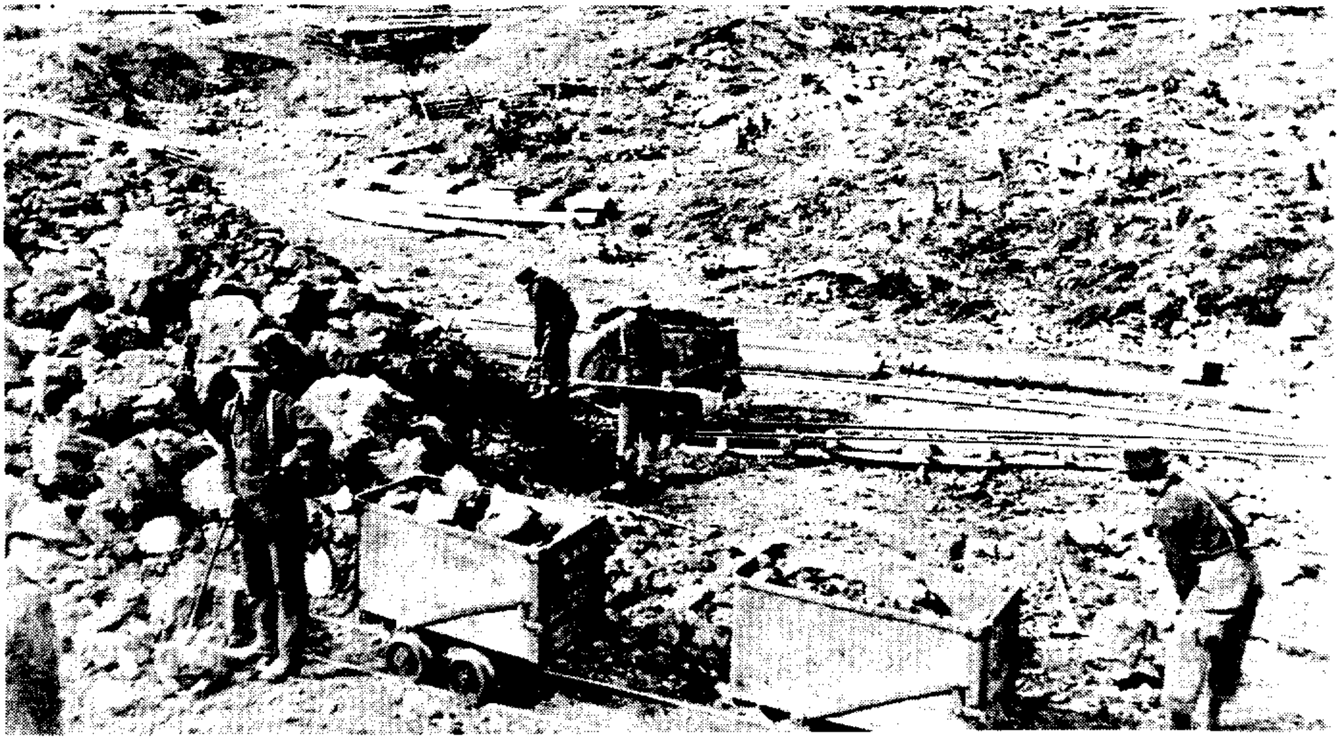

Photo 3: *Moving rock in 1913. Loading ore cars with rock from the Pueblo glory hole.*

4. EXPLORATION (1946-1990)

Exploration methods during this period became more sophisticated utilizing surface geological mapping, **geophysical surveys**, **geochemical surveys** and diamond drilling to locate and test targets. Unlike the methods used in the early 1900's, systematic exploration programs were undertaken prior to mining. This allowed mining companies to assess the economics of mining various copper skarn **orebodies** before initiating expensive development work.

Between 1946 and 1963 sporadic exploration by Noranda Mines, Hudson Bay Mining and Smelting Co. Ltd.and Imperial Mines and Metals Ltd. consisted mainly of geological surface mapping, geophysical surveys and diamond drilling. Geophysical surveying measures the physical properties of rock such as magnetism or electrical conductivity.

Magnetic surveys were relatively new in 1946. They used a **magnetometer** which could be carried by one person across the surface to measure the magnetic attraction (susceptibility) of the underlying rocks. This proved to be very useful on the Copper Belt since magnetite is a common mineral found in the skarn deposits. One problem, however, was the Miles Canyon basalt which commonly had magnetometer readings that fell within the **anomaly** range expected for the magnetite skarns (Hart and Pelletier, 1989).

Magnetometer surveys were successful in locating the Arctic Chief East, the northward extension of the Valerie and the Gem-Black Cub and Cub South zones (Tenney, 1981).

Induced polarization (or IP) surveys were also successfully used in the Copper Belt. IP surveys employ an electrical current to determine indications of mineralization. Since the copper in the skarn deposits occurs as disseminated ore minerals (such as chalcopyrite and bornite) which are highly conductive, IP anomalies were a good indicator of mineralization.

Geochemical surveys were first used in the Whitehorse Copper Belt in 1969 (Tenney, 1981). This involved taking soil samples at regular intervals along a surface grid and analyzing them for copper values. Anomalies indicate possible buried copper skarn deposits. This technique was not very successful because the transported glacial overburden was not representative of the underlying bedrock.

Geological mapping, geophysics and geochemistry were all used to locate targets for diesel-powered diamond drills. From 1956 through 1967 New Imperial Mines completed 116,088 feet (35,384 m) of diamond drilling in 332 holes on their War Eagle, Arctic Chief, Keewanaw, Cowley Park, Best Chance, and Little Chief prospects (Kenway, 1968).

From 1967 to 1990 exploration continued on a sporadic basis consisting mainly of detailed geophysics to identify favourable targets followed by diamond drilling to test the targets.

5. OPEN PIT MINING (1967-1971)

Orebodies which are close to surface can be mined using inexpensive open pit methods. Cost advantages of open pit compared to underground mining lie mainly with the size of equipment used and the economies of scale they provide. The size and power of open pit mining equipment are not restricttrucks capable of carrying 35 tons (31.7 tonnes) of material were used. Large drills were used to drill blastholes faster and on a larger scale than what is possible underground (Hilker, 1967).

Open pit mining was conducted in seven pits which included: Little Chief, Arctic Chief East, Arctic Chief West, War Eagle South, War Eagle North, Black Cub South,and Keewenaw. The average **stripping ratio** for all the deposits was 3:1 or 3 tons of waste for every ton of ore (Tenney, 1981).

The smaller pits such as the two Arctic Chief pits were mined as open cuts. These were similar to the steep-sided glory holes of the early 1900's except for the use of large mechanized equipment to blast and haul.

The larger pits like the Little Chief were mined in 25 foot (7.6 m) thick horizontal benches. The first bench would be the largest and would determine how deep the mine could go, since each successive bench had to be smaller than the benches above.

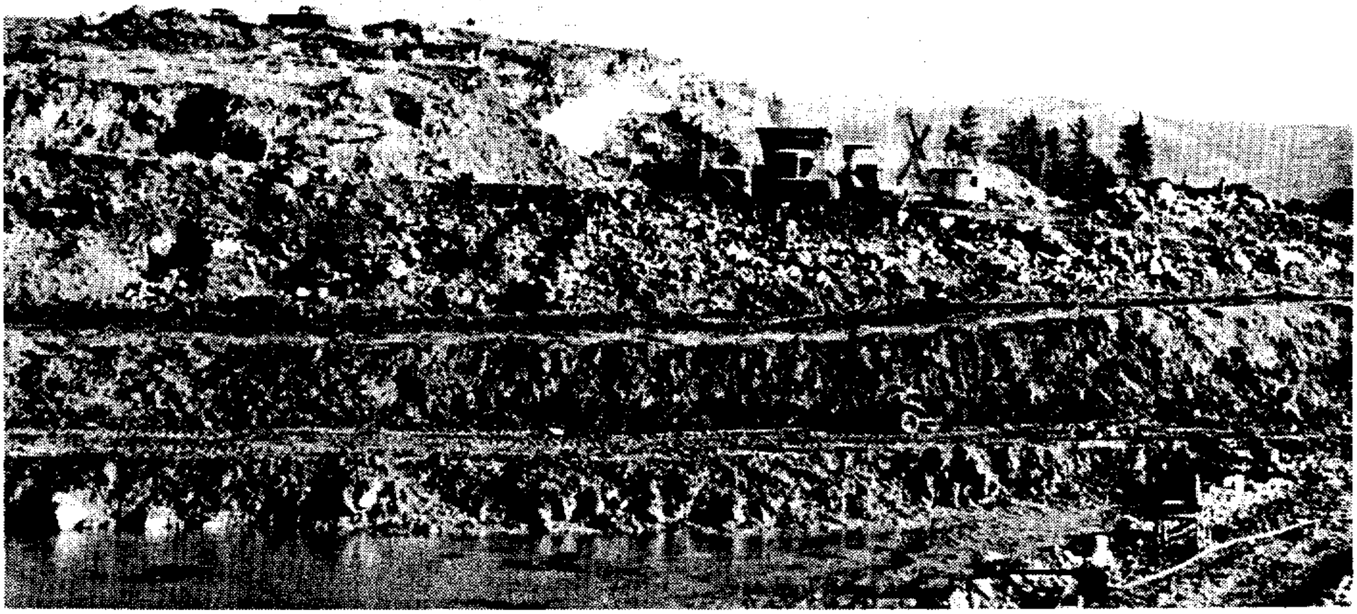

Photo 4: *Top benches of an open pit with an excavator and front-end loader filling 35 ton Euclid.*

Photo 5: *Open pit mining: side view showing 35 ton Euclid truck being loaded.*

In the pit, large blasthole drills would be used to drill each bench prior to blasting. The rock cuttings from the drill hole would be sampled to determine if that hole was in ore or waste rock. The holes were drilled on a 18 foot (5.5 m) triangular pattern with large areas drilled and blasted at one time (Kenway, 1968).

After the blast, the ore and waste would be marked out and loaded into 35 ton haul and dump trucks with ore sent to the mill and waste to the waste pile. The ability to separate ore from waste after a production blast is an important method of increasing efficiency in open pits which is difficult to do when underground mining.

The Little Chief open pit was the largest in the Copper Belt with a total of almost 2.4 million

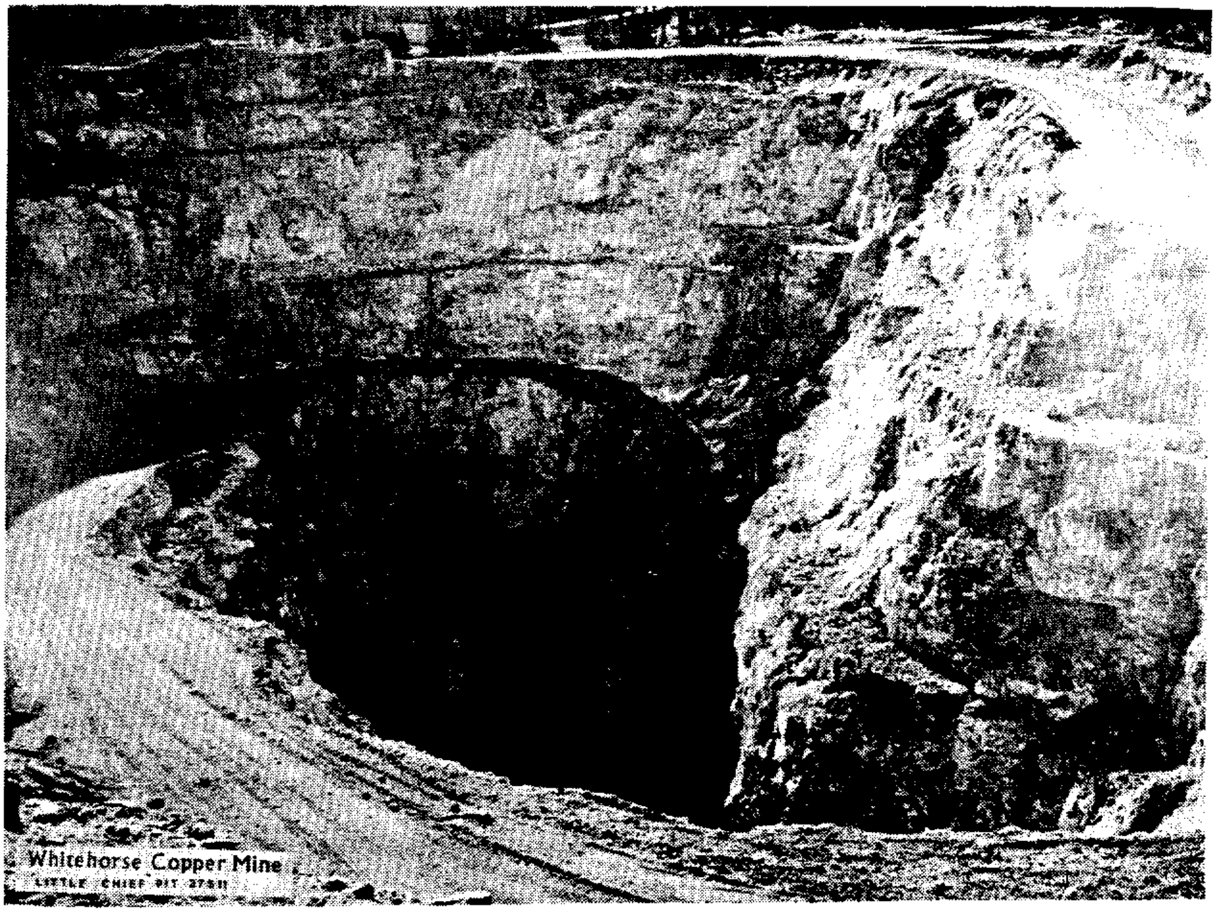

Photo 6: *Whitehorse Copper Mine, Little Chief Pit after open pit mining had ceased.*

tons (2.2 tonnes) of ore and waste mined. By comparison, between 260 and 280 million tons (236 to 254 tonnes) of rock have been removed from the Faro open pit, which is the largest lead-zinc open pit mine in the world (Jilson, pers. comm).

6. UNDERGROUND MINING (1972-1982)

6.1 Introduction

Recent underground mining in the Whitehorse Copper Belt was performed by Whitehorse Copper Mines at the Little Chief and Middle Chief deposits between 1972 and 1982. After the near surface ore was removed from an open pit to a depth of 300 feet (91.4 m) an underground extension was designed to recover the deeper ore which continued for another 1000 feet (300 m).

6.2 Mining Techniques

Mining techniques evolved over the life of the mine and illustrate adaptation to the unstable ground conditions encountered. Between 1972 and 1979 approximately 70% of the orebody was mined using sub-level open stoping, then in 1979 an innovative technique called vertical crater retreat was adopted.

Sub-level open stoping was similar to the methods used by miners in the early 1900's but on a much larger scale. Stopes up to 190 feet (57 metres) long and 200 feet (60 metres) high were excavated from a particular sub-level, with pillars left between stopes to support the overlying ground. Once the level was mined out, activity would move to a lower level where the process was repeated.

The poor ground conditions made it difficult to use this technique effectively at Whitehorse Copper. Because the ore was fractured, pillars caved before the extraction of broken ore in the stopes was completed (Tenney, 1981). Waste rock from above would fall into the stopes and dilute the ore, causing the ore to be mined at a lower copper grade than expected. This seriously affected the profitability of the mine, as well as providing an on-going hazard to workers.

In 1979 Whitehorse Copper became one of the first mines in Canada to use vertical crater retreat (VCR) mining. VCR made it possible to mine out an entire part of the orebody without leaving pillars for ground support.

Two drifts at different sub-levels are driven across the top of the orebody (or the process can be done from surface into a lower sub-level). Large diameter holes are drilled vertically down through to the lower sub-level. The bottoms of the holes are loaded with explosives (ammonia nitrate) and blasted. This allows broken ore to fall into the bottom sub-level as successive horizontal slices, using the same blastholes for each successive blast. Ore is mucked from the bottom sub-level, providing room for the next blast. This controlled blasting decreases the chance of waste rock caving into the stope and therefore controls dilution.

This mining method is also much safer since the miner does not enter the area where the ore is blasted. All drilling and loading of the holes is done from the top and mucking is done using remote-controlled **LHD**'s (load haul dump units or scoop trams). VCR also eliminates the need to support the ground after each blast.

6.3 Haulage, Crushing, Hoisting

The Whitehorse Copper Mine was serviced by a decline that started at surface (elevation 2639) and followed a zigzag course downward to just below the 1700 foot level (the elevation above sea level, as opposed to depth from surface).

A 1250 foot (381 metres) shaft ran from surface with stations at the 2000 and 1700 foot elevation with a loading pocket at 1518. The shaft was concrete lined, with steel dividers separating it into two sections approximately six feet square, and a manway. It was topped by a 112 foot (34 metres) headframe (Pazour, 1979).

Photo 7: *Miners removing loose material from the roof of a drift after a blast (scaling).*

During mining, ore was extracted through drawpoints in the stope and taken by LHD's to an ore pass. To prevent plugging the ore pass with oversized ore it was covered by a **grizzly** (a screen made of steel rails set 36 inches (0.9 metres) apart). Oversize ore caught by the grizzly was broken down by a pneumatic hammer or by secondary blasting (Western Miner, 1974).

The ore fell through the ore passes to locomotive-driven ore cars on the tramming level and was taken to the shaft for hoisting to the primary crusher at the surface (Figure 6).

In 1974 a **jaw crusher** was installed underground at the 1700 foot level (New Imperial Mines Ltd. Annual Report 1974). In 1979 with the advent of VCR a jaw crusher was also installed on the 1300 foot level.

After passing through the crusher, ore was transported to the shaft using three conveyor belts with a total length of 2,000 feet (610 metres). The conveyors fed a shaft loading pocket from which the ore was hoisted to surface in two 6 ton (5.4 tonne) skips (Pazour, 1979).

A ventilation system was installed in the mine due to the hazardous fumes resulting from diesel powered equipment and from blasting. Huge fans at the surface pumped fresh air down the shaft and along various sub-levels to the mine workings. Vent raises (vertical tunnels) were drilled from the mine workings up to the surface to provide fresh circulating air throughout the mine (Whiteway, 1990.)

During the winter months heaters on the ventilation system were used to preheat mine air to 7°C. In the early days of underground development before the shaft was finished, waste hauling from within the mine to the surface in winter was a harrowing experience. As the LHD units drove up the decline they would heat an envelope of air around the machine to 25° or 30°C. When they exited into the open air the driver would often experience a temperature drop of some 65°C to minus 40°C (Pazour, 1979).

Water was drained from Little Chief Lake prior to development of the deposit (New Imperial Mines Annual Report 1966), and during the life of the mine water was pumped out at a rate of 105 gallons (477 litres) per minute (Pazour, 1979).

All maintenance and rebuilding of equipment was done on the property. The "Clarkmobile", a modified LHD unit, was developed here under the guidance of Clark VanSteinburg, and received much attention from the Canadian mining industry.

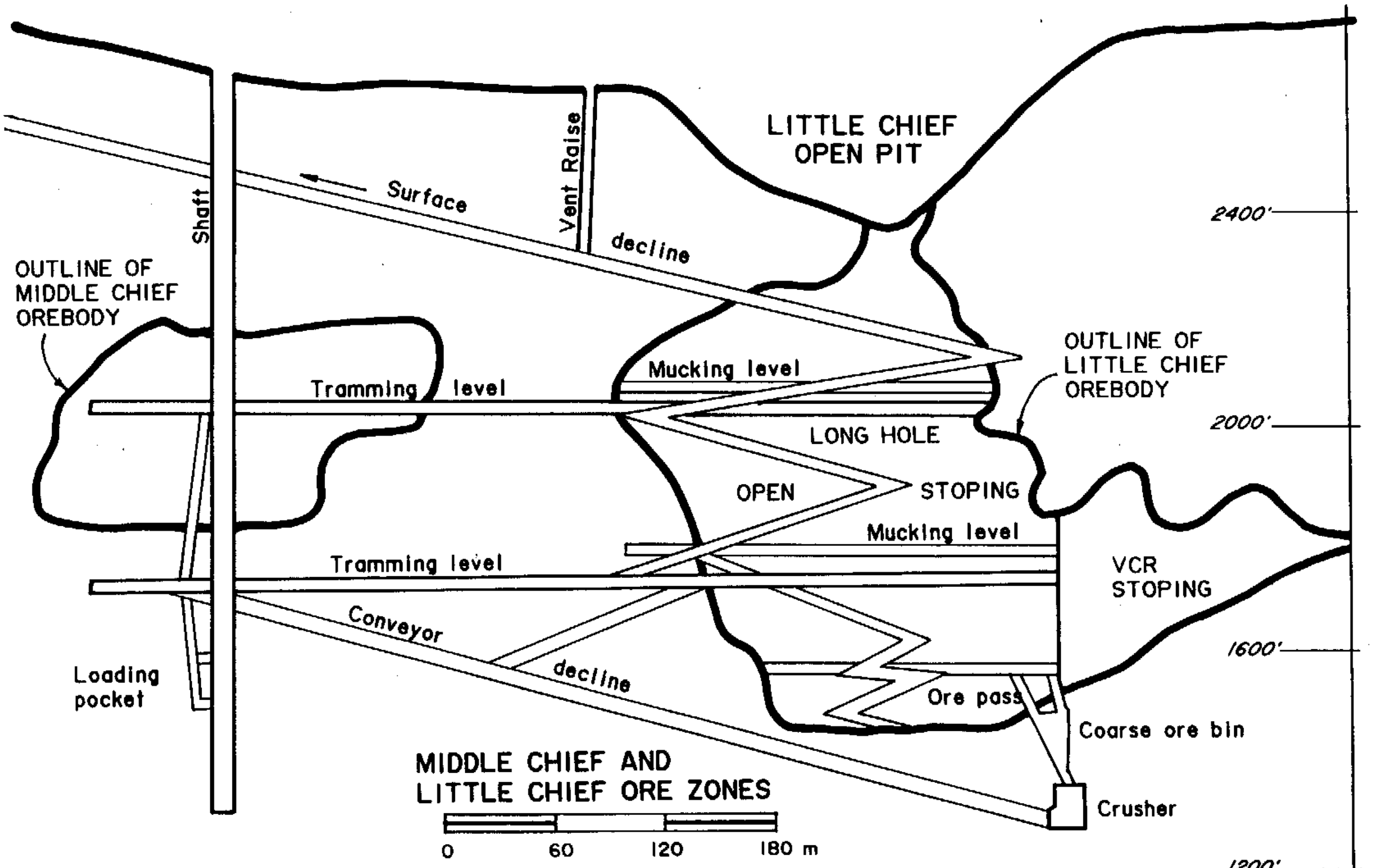

FIGURE 6 : Schematic Cross-section of Underground Workings at the Little Chief Deposit (adapted from Pazour,1979)

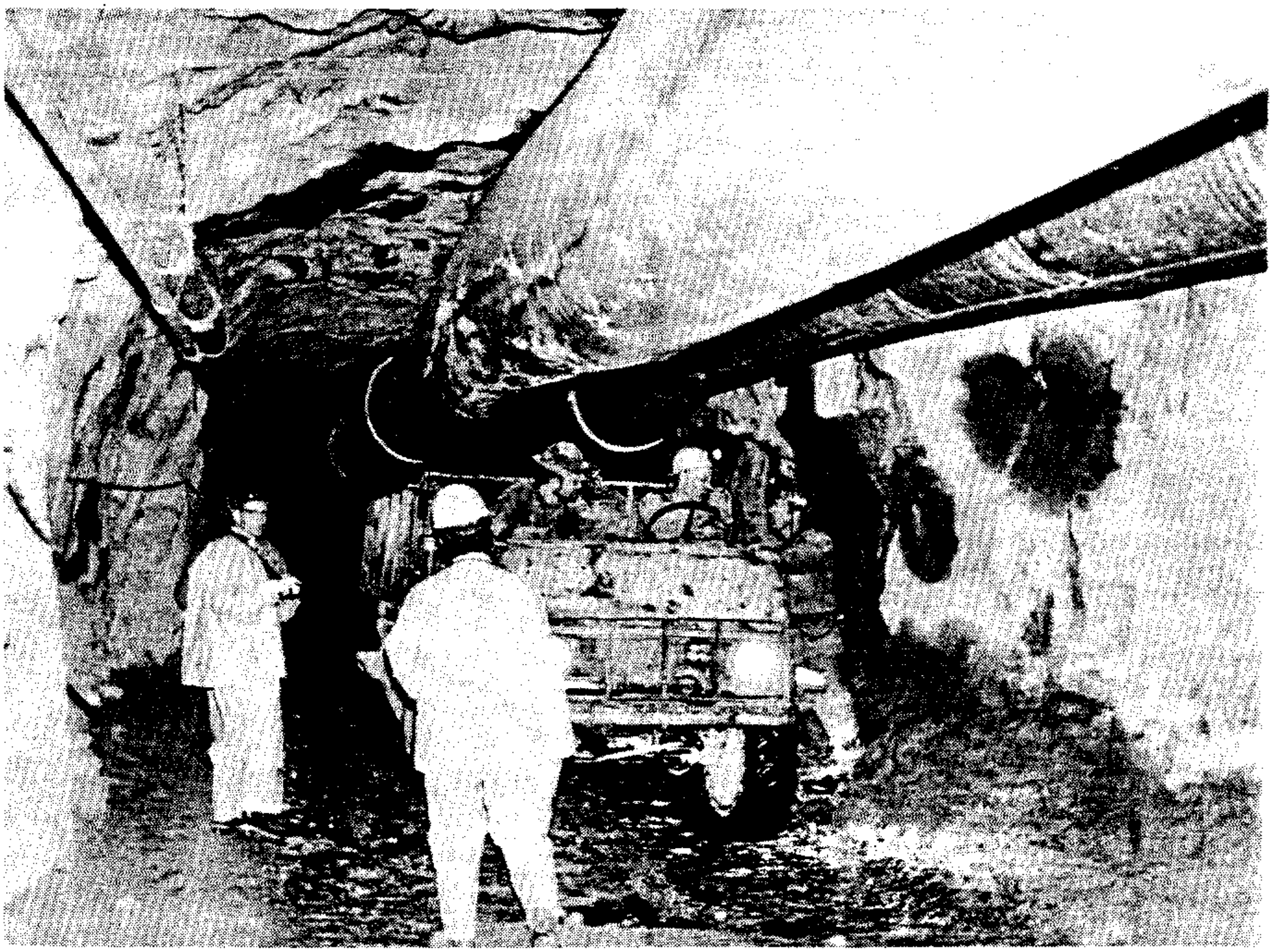

Photo 8: *Underground at Whitehorse Copper Mine: "trackless" Mercedes Unimog man carrier, ventilation ducts.*

The Whitehorse Copper underground mine at Little Chief was closed December 22, 1982 when depleted reserves and a drop in copper prices made it uneconomic to continue.

7. MILLING

7.1 Introduction

The purpose of the milling circuit was to separate the copper-bearing minerals from the ore, creating a copper concentrate.

From 1968 to 1982 the **head grade** (copper grade of ore going into the Whitehorse Copper Mill) averaged about 1.5% copper. After milling this grade was increased to about 42% in the final copper concentrate. This greatly reduced the amount of material that had to be shipped to outside smelters while still recovering about 88% of the copper.

Gold and silver in the ore is associated with the copper minerals and is mostly recovered in the copper concentrate.

In the early 1900's copper ore was shipped directly from the mines. This meant that only high grade ore could be mined and shipped at a profit. Small shipments often had the copper grade increased by hand sorting to manually create a concentrated ore. The first ore shipped from the Copper Belt was 9 tons (8.2 tonnes) of hand picked ore which graded 46.4% (Hilker, 1968). However, without abundant cheap labour large-scale hand sorting was impractical.

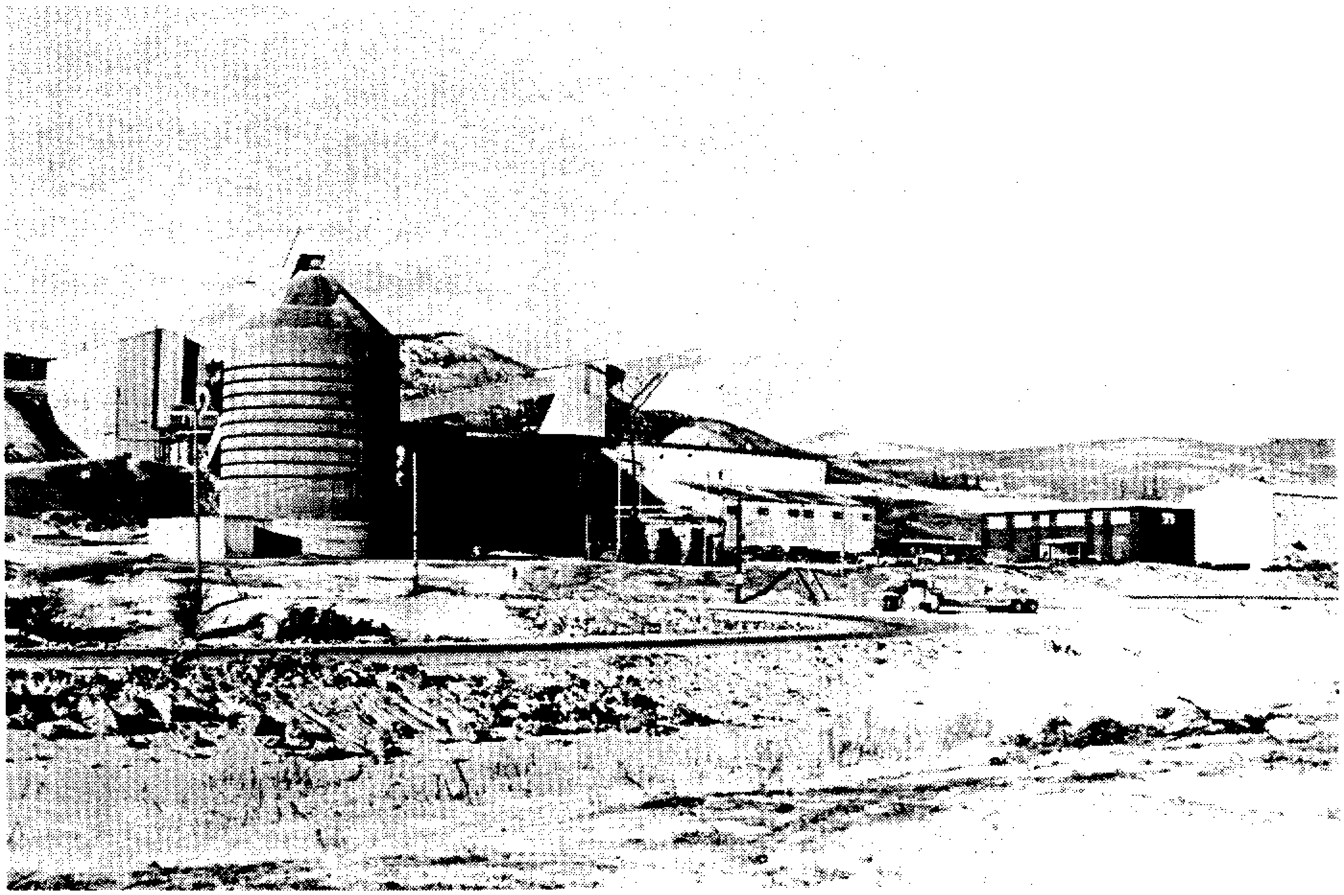

Photo 9: *Whitehorse Copper Mines surface facilities. From left to right: crusher, fine ore storage bin, concentrator, office building.*

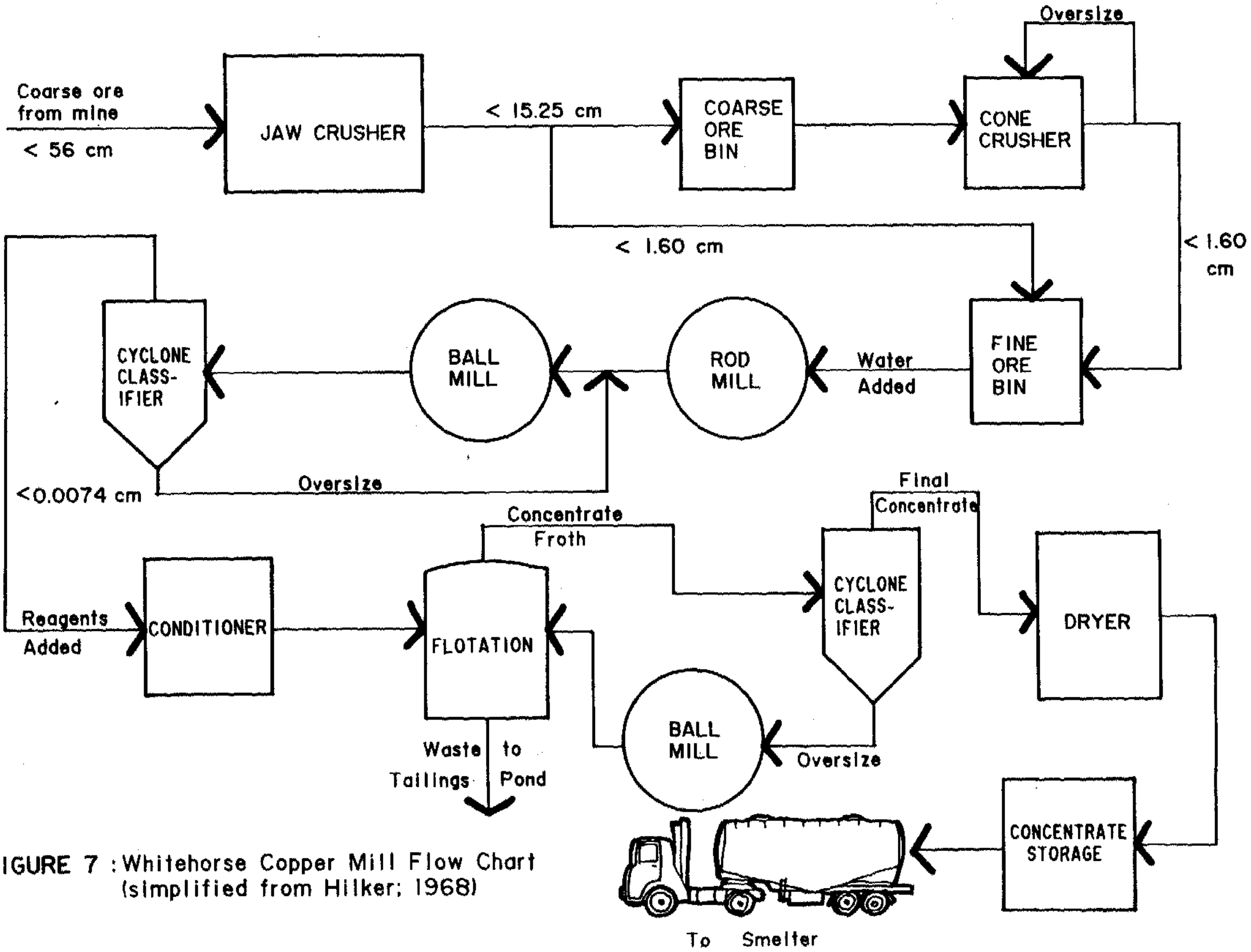

FIGURE 7 : Whitehorse Copper Mill Flow Chart (simplified from Hilker; 1968)

Without a concentrator the production of 140,000 tons (127,000 tonnes) from the Pueblo (which graded 3.5%) had to be shipped in its entirety (Pazour, 1979). The copper content of 4900 lbs (2200 kg) would be recovered at the smelter. If that same ore had been run through the Whitehorse Copper Mill built in 1968, only 10,266 tons (10,431 tonnes) would have had to be shipped but only 4312 lbs (1956 kg) of copper would have been recovered. The remaining 588 lbs (266.7 kg) of copper would be lost to the waste (tailings) during milling.

This analysis completely ignores the **metallurgy** of the minerals which contain the copper. The Whitehorse Copper mill was designed to recover the copper-bearing sulphide minerals chalcopyrite and bornite. At the Pueblo mine the copper occurs predominantly in the minerals malachite, azurite, chrysocolla ($Cu_4H_4Si_4O_{10}(OH)_8$) and cuprite (Cu_2O) (McConnell, 1909). Therefore, the Whitehorse Copper mill would actually have been able to recover very little of the copper from the Pueblo deposit. At the smelter the metallurgy is unimportant because the smelting process breaks the down the minerals themselves.

7.2 Milling Process

The basic steps in the milling process involve breaking the ore down into its individual minerals, using chemicals to separate the copper bearing minerals from the waste, and drying the resulting copper concentrate to prepare it for shipping (Figure 7).

7.21 Crushing/grinding

These circuits reduced the ore to a grain size small enough to liberate the individual mineral grains. Reducing the broken chunks of ore to a fine grit by the use of various rock crushers and grinding mills was done in several steps.

Coarse ore was passed through a grizzly with rails set 22 inches (56 centimetres) apart. Ore that would not pass through the grizzly was broken up using a pneumatic hammer or by secondary blasting.

Once the ore had passed through the grizzly it was brought to the jaw crusher. The jaw crusher consisted of two heavy steel plates set in a "V" with the size of ore that passed on controlled by the gap at the bottom of the "V". This reduced the ore to a 15 cm (6 inch) diameter.

Material finer than 1.6 cm (5/8") was passed directly to the 6,000 ton (5440 tonne) fine ore bin for storage. The coarser ore was passed into the coarse ore bin.

From the coarse ore bin the ore passed through two cone crushers that broke the ore down to less than 1.6 cm (5/8 inch). The ore was then passed to the fine ore bin.

Crushed ore from the fine ore bin was fed together with water into the grinding circuit, which included both **a rod mill** and a **ball mill**. Large steel rods or balls revolved and cascaded within the respective mills, grinding the ore into a fine pulp.

The slurry was then spun through a **cyclone classifier** which separated different size particles. The larger and heavier particles sank to the bottom of the cyclone where they were returned to the ball mill for further grinding, while the finer particles (~65% <0.0074 cm) escaped from the top of the cyclone and were passed on to the flotation circuit.

The maintenance crew cleaning the pump boxes between the rod mill and the cyclone classifiers were the first to discover significant coarse gold at Whitehorse Copper. These pump boxes had acted like sluice boxes, trapping the heavy gold from the tons of slurry that passed through them. By 1978 the mill had installed equipment to recover this gold and that year they recovered about 1200 ounces (Pazour, 1978).

7.22 Flotation

The fine slurry of ore and water was then mixed with chemical **reagents** in the conditioner tank and pumped into a series of **flotation cells**. Slurry entered the flotation cell half way up and air was bubbled into the cell from the bottom. The reagents cause the copper-bearing minerals to stick to the bubbles, concentrating the copper minerals in the froth at the top of the flotation cell.

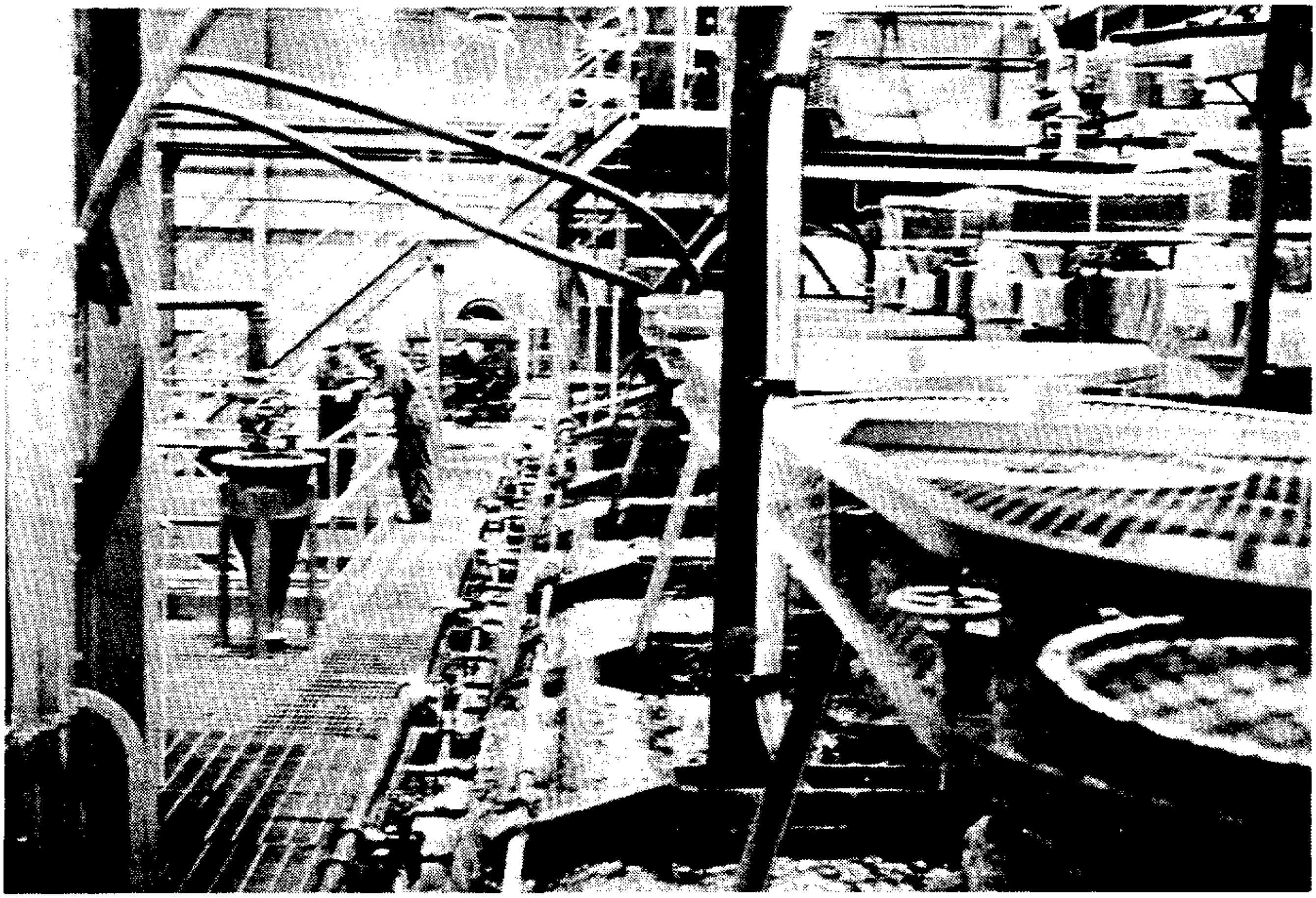

Photo 10: *Interior of Whitehorse Copper Mine mill. In foreground copper-rich froth spills from flotation cells.*

Next the froth was skimmed and put through another cyclone classifier. The material that passed through the top of the cyclone was dried to become the final concentrate. The heavy material that fell through the bottom of the cyclone was re-ground in another ball mill and feed back into the flotation cell.

7.23 Drying

The drying stage was very important since it reduced the weight of the concentrate, and therefore the shipping costs. Problems associated with freezing solid blocks of concentrate were also minimized when the concentrate was dried properly.

At Whitehorse Copper the mineral-bearing bubbles were put through various thickeners and filters to remove the water. This dried concentrate contained approximately 12% moisture. Because shipping costs were so high a further step was added and the concentrate was put through an oil-fired dryer to reduce the moisture content to 4% before shipping (Pazour, 1979).

8. MAJOR DEPOSITS

8.1 Cowley Park

The Cowley Park deposit occurs at the south end of the Copper Belt, near the junction between the Alaska Highway and the South Klondike Highway. It consists of a roof pendant of limestone 1000 ft by 330 ft by 330 ft (300 m x 100 m x 100 m) thick enclosed by the granite pluton (Figure 8).

Cowley Park is a calc-silicate skarn. The major minerals include garnet, diopside, actinolite, tremolite and wollastonite with minor serpentinite and magnetite. The ore minerals contained in the skarn are chalcopyrite and bornite with significant amounts of molybdenite (MoS_2) and minor gold & silver values (Tenney, 1981).

Cowley Park was explored with two shafts in 1913. No work is noted prior to that and little activity followed for half a century. In 1963 New Imperial Mines began to outline the deposit with diamond drilling. In 1971 they conducted extensive diamond drilling on the north central flank of the pendant and defined an open-pittable reserve of 975,000 ton (884,000 tonnes) of potential ore grading 1.04% copper, 0.21 g/t gold, 3.77 g/t silver and 0.066% molybdenite with a stripping ratio of 2.3:1. A further 736,800 tons (668,000 tonnes) of potential ore grading 0.9% copper was also defined as underground reserves (Watson, 1984).

When copper prices were high in the 1970's this was considered a marginally profitable deposit, but when prices declined sharply in 1981 it became uneconomic to continue to develop (Tenney, pers. comm.). Except for the minor underground work in the early 1900's and a 5000 ton (4500 tonne) test pit in the 1970's, Cowley Park was never mined and remains the largest open-pittable reserve in the Copper Belt today.

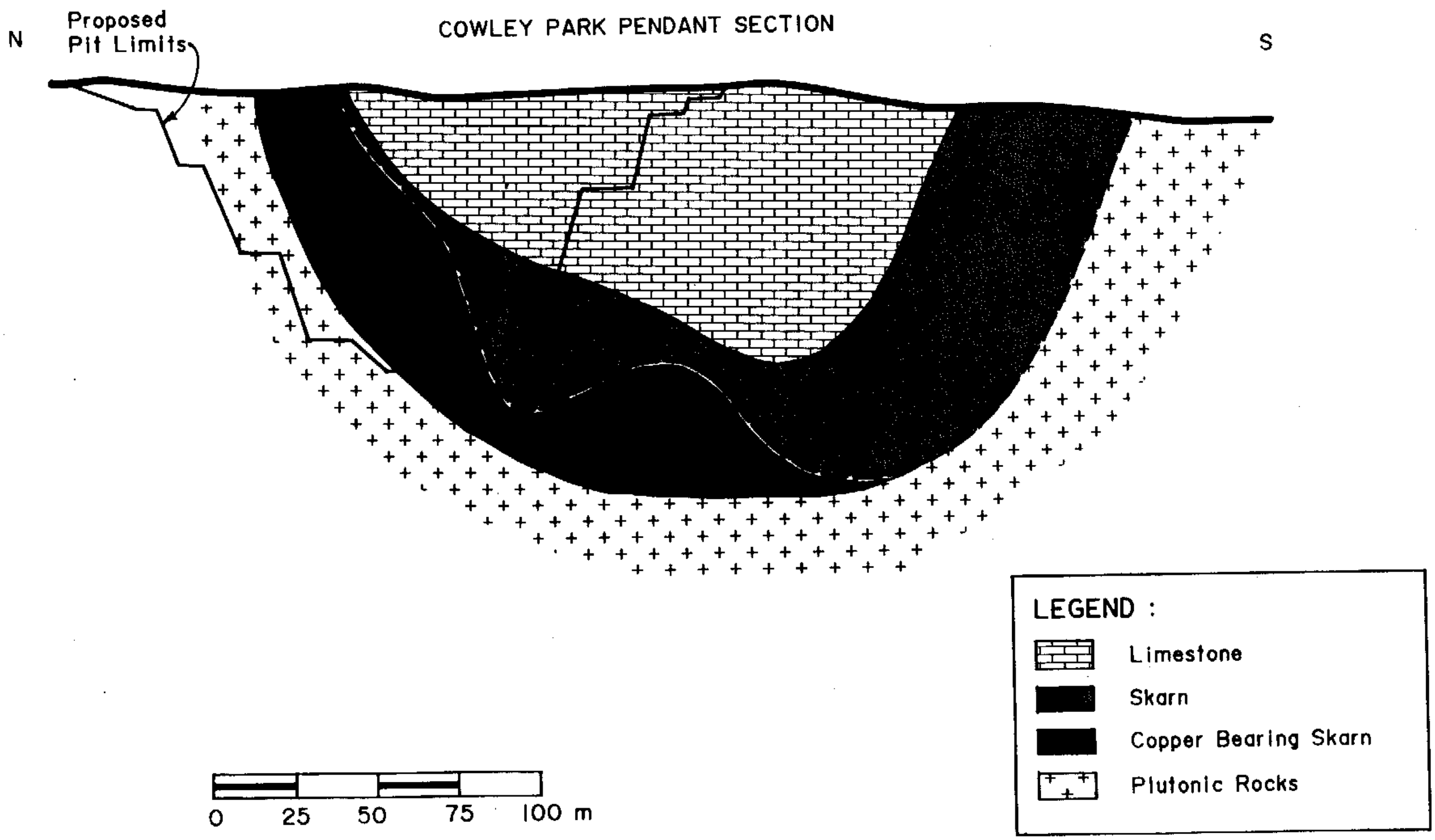

FIGURE 8 : Geological Cross-section of the Cowley Park Main Zone with Limits of Proposed (1979) Pit Design. The Geology Shown is as Reinterpreted by G. Morrison. (adapted from Tenney, 1981)

8.2 Gem-Black Cub Area

The Gem-Black Cub area near the south end of the belt includes six iron-rich skarns within a one kilometre long northwest-trending peninsula of limestone, surrounded on three sides by plutonic rocks. The deposits include the North and South Black Cub, Brown Cub, Grizzly Cub, Kodiak Cub and Gem deposits.

The skarn minerals contained in these deposits consist mainly of serpentinite and magnetite. The copper-bearing minerals are chalcopyrite, bornite, chalcocite (Cu_2S)and an unusual copper mineral, valleriite ($(Fe,Cu)S_2$ $(Mg,Al)(OH)$) (Morrison, 1981).

Prior to 1909 short shafts were driven on the Black Cub and the Brown Cub but no ore shipments were reported.

Of these deposits only the Black Cub South was ever mined. In 1971 206,000 tons (187,000 tonnes) of ore grading 1.3% copper, 0.24 g/t gold, 12.34 g/t silver were removed from an open pit (Watson, 1984). Difficulty in recovering copper from valleriite (because of its unusual chemistry) in the mill flotation caused low overall copper recoveries.

The Gem deposit, discovered in 1967 by a magnetometer survey, also received serious exploration attention. Diamond drilling outlined an open-pittable reserve of 690,000 tons (625,000 tonnes) of 1.0% copper with a stripping ratio of 3.3:1. However, due to the presence of copper oxide minerals and valleriite, copper recoveries from a small test pit using standard flotation methods reached a maximum of only 60% (Tenney, 1981). This poor recovery prevented the deposit from being mined.

8.3 Keewenaw

The Keewenaw orebody, just 1600 feet (500 metres) west of the Gem deposit, is the only deposit in the belt that occurs in the granite pluton. It consists of skarnified plutonic rocks rich in chlorite and garnet, with quartz, epidote, calcite and chalcopyrite in veins. Other sulphide minerals include bornite, chalcocite, covellite (CuS) (Morrison, 1981).

This deposit was open pit mined in 1971 and 175,000 tons (159,000 tonnes) of 1.0% copper were extracted (Watson, 1984). In the oxidized upper parts of the deposit the sulphide minerals have altered to cuprite, malachite, azurite, and chrysocolla. These minerals reduced copper recovery to 33% in mill tests (Tenney, 1981). Consequently much of the upper portion of the deposit was removed as waste. Today these waste dumps along the haulage road in the Wolf Creek Valley exhibit the characteristic bright blue and green colours of malachite and azurite.

Deeper in the Keewenaw pit, where the copper sulphide minerals were unaltered, milling recovered eighty to ninety percent of the copper from the ore (Tenney, pers. comm.). In 1971 falling copper prices, from a high of 70 cents per pound in 1970 to a low of 53 cents per pound in 1971, forced the closure of this mine. A reserve of 222,800 tons (202,000 tonnes) of 1.0% copper still remains at the bottom of the pit today (Watson, 1984).

8.4 Arctic Chief

The Arctic Chief deposit is an iron-rich skarn with magnetite and diopside as the main skarn minerals. This deposit lies on the western edge of a large limestone roof pendant. Although small, the Arctic Chief deposit contains the highest gold and silver grades in the copper belt (Tenney, 1981; McConnell, 1909). The main copper bearing minerals are chalcopyrite with lesser bornite and minor valleriite.

Claims were first staked over the deposit in 1899. In 1904 140 tons (127 tonnes) of ore was shipped which graded 7.22% copper and 0.39 oz/ton gold. In 1907 a second shipment of 83 tons (75 tonnes) graded 5.37% copper and 0.18 oz/ton gold (Kindle, 1963).

In 1968 and 1969, New Imperial Mines Ltd. mined two small open pits and extracted 225,585 tons (201,800 tonnes) of ore grading 1.44% copper, 1.03 g/t gold and 17.14 g/t silver (Watson, 1984).

8.5 Best Chance-Grafter

Several small banded skarns north of the Arctic Chief deposit are made up of diopside, garnet calc-silicate lenses and smaller patches of magnetite, serpentine and epidote iron-rich skarns. Copper primarily occurs as chalcopyrite with lesser bornite and is restricted to the iron-rich skarns (McConnell, 1909).

The Grafter produced 13,450 tons (12,200 tonnes) of 6% copper prior to 1917 (Watson, 1984). Although the Best Chance deposit received minor underground exploration work in the early 1900's, no production was recorded then.

New Imperial Mines conducted diamond drilling on the Best Chance deposit during the 1960's and outlined an open-pittable reserve of 493,000 tons (447,000 tonnes) grading 0.71% copper (Tenney, 1981). However, due to its low grade the deposit was never mined.

8.6 Pueblo

The Pueblo deposit is a series of steep easterly dipping lenses of skarn that occur along a north-trending fault zone between the limestone and plutonic contact. The mineralization is also cut by the northwest-trending Porter Creek fault that postdates the mineralization. The deposit has characteristics of both iron-rich and calc-silicate skarn types. The presence of magnetite and hematite (Fe_2O_3) suggest that it is an iron-rich skarn while the lack of serpentine and the presence of garnet, diopside and wollastonite suggest that it is a calc-silicate skarn.

The faulted nature of the ore body has allowed deep oxidation, making the Pueblo unique since it is the only deposit consisting of dominantly non-sulphide ore minerals. The only copper sulphide mineral is minor remnant chalcopyrite. The copper ore minerals are malachite, azurite, cuprite and chrysocolla (Figure 9).

The Pueblo mine, by far the largest of the early mines, had a main shaft more than 500 feet (152 m) deep with level workings every 100 feet (30.5 m). By 1916 the mine was producing ore at a rate of

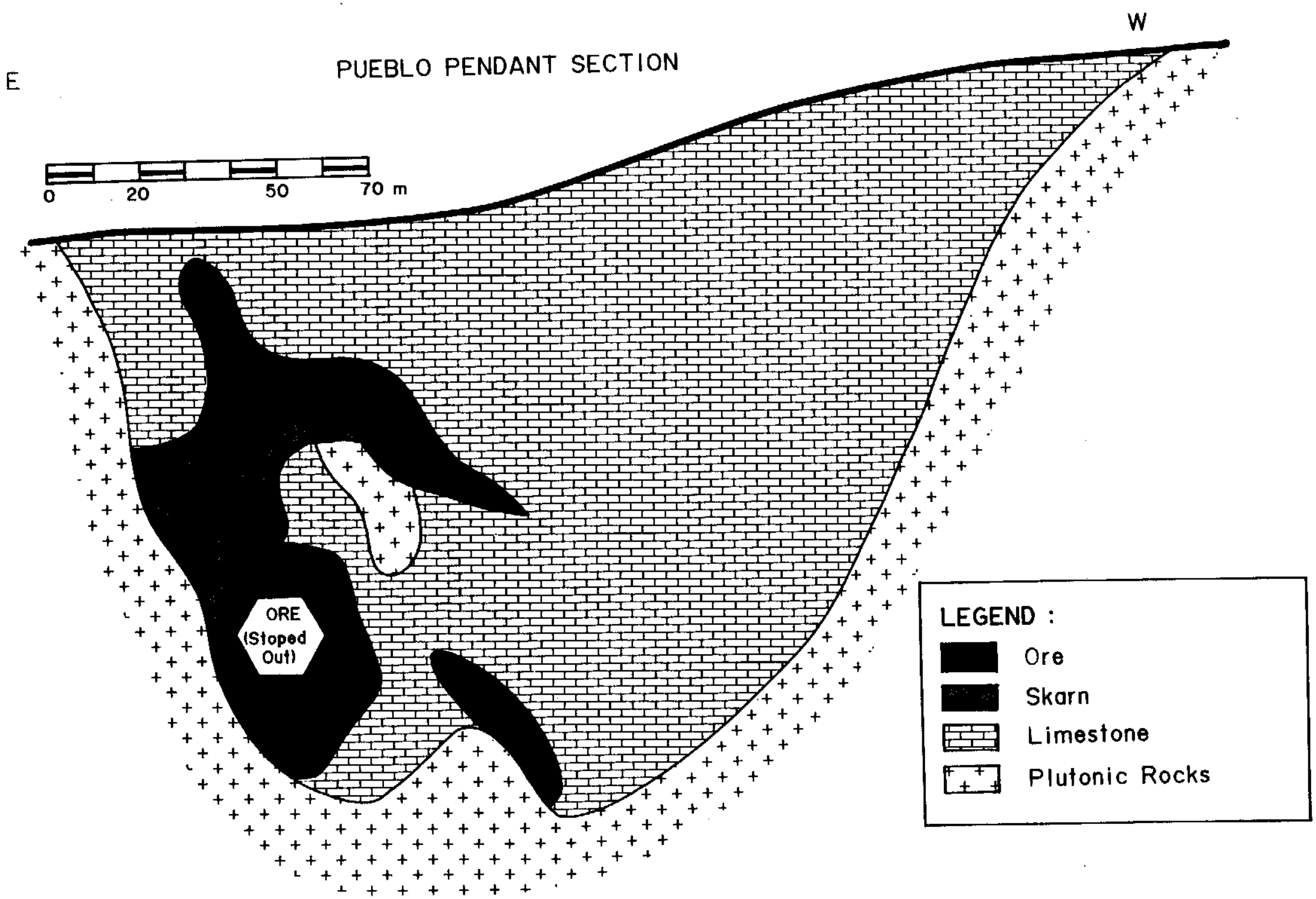

FIGURE 9 : Schematic Geological Cross-section of the Pueblo Pendant. Down Dip Potential for More Ore is Limited as the Diorite Contact Cuts Off the Sedimentary Rocks. (adapted from Tenney, 1981)

125 tons each day. The Pueblo shipped 140,780 tons (127,635 tonnes) grading 3.5% copper between 1912 and 1920 accounting for 86% of the early production of the entire copper belt (Watson, 1984).

8.7 War Eagle

The War Eagle deposit is at the northern end of the Copper Belt. Unlike all of the other deposits in the Belt, the contact with the main granite pluton has not been encountered in drilling or mining, although it is believed to be approximately 1000 feet (300 m) east of the deposit (Morrison, 1981).

The War Eagle is a typical calc-silicate skarn consisting of garnet, diopside and wollastonite with little or no magnetite and serpentine. The ore minerals are chalcopyrite and bornite. Minor molybdenite is also present but was never recovered.

Limited underground mining occurred prior to 1915 and 900 tonnes grading 5.7% copper, 1.03 g/t gold and 68.57 g/t silver were extracted. In 1970 and 1971, 991,600 tons (899,000 tonnes) of ore grading 1.25% copper, 0.22 g/t gold, 8.57 g/t silver and 0.038% molybdenite were mined from two open pits by New Imperial Mines Ltd. (Watson, 1984).

8.8 Copper King-Carlisle

The Copper King and the Carlisle occur on the west and east side respectively of a north-trending embayment of limestone and siltstone into the north end of the granite pluton. Both deposits are hosted in calc-silicate skarn consisting mainly of garnet, diopside and wollastonite. The main ore-bearing minerals are bornite and chalcopyrite. Minor molybdenite is also present.

The Copper King was the first deposit in the Copper Belt to be staked. By 1900, 9 tons (8.2 tonnes) of extremely high grade copper ore grading 46.40% copper was mined. This was the first shipment of ore from the Whitehorse Copper Belt (Tenney, 1981). By 1907, 560 tons (508 tonnes) averaging more than 15% copper had been shipped. From 1915 to 1920, with the addition of a steam driven hoist and five compressed air powered drills, the mine produced 5294 tons (4,800 tonnes) or ore grading 1.47% copper, 0.17 g/t gold and 15.09 g/t silver (Watson, 1984). The grade of the later shipment seems questionable since Kindle (1963) reports a shipment of similar tonnage at a grade of 10% Cu. With the high shipping costs it is highly unlikely that a shipment grading as low as Watson reports could return a profit for the operator.

8.9 Little Chief

The Little Chief deposit was the largest orebody in the Whitehorse Copper Belt, with a total production of approximately 9,649,044 tons (8,748,000 tonnes) averaging 1.5% copper (Watson, 1984).

The orebody, along with the smaller Middle Chief and Big Chief skarns occur in a northeast-trending embayment of limestone, limy siltstones and sandstones on the western margin of the granitic pluton (Figure 10). The skarns are dominantly iron-rich with the main skarn minerals being magnetite and serpentinite. Calc-silicate skarn with garnet and diopside as the main minerals are also present but do not contain a significant amount of ore (Morrison, 1981).

The Little Chief and Middle Chief ore zones were probably one orebody which was broken into two parts by an east-trending fault (Morrison, 1981).

The whole orebody was approximately 1500 feet long, 100 to 150 feet thick and 1300 feet deep (457 m x 30.5 - 45.7 m x 396 m) with a total reserve of approximately 10,000,000 tons (9,070,000 tonnes) of 2% copper (Morrison, 1981). Copper occurs in a variety of minerals with bornite, chalcocite, and to a lesser extent chalcopyrite and valleriite being the most common. The main secondary minerals, formed by the weathering of the primary copper minerals, are cuprite, covellite, malachite, azurite and chrysocolla (Morrison, 1981). Important values of gold and silver, averaging 0.75 g/t and 9.16 g/t respectively, are also present (Watson, 1984).

The Little Chief was one of the first deposits staked in the belt but it received little work during the early 1900's. Although the tonnage potential was greater, the relative low grade when compared to

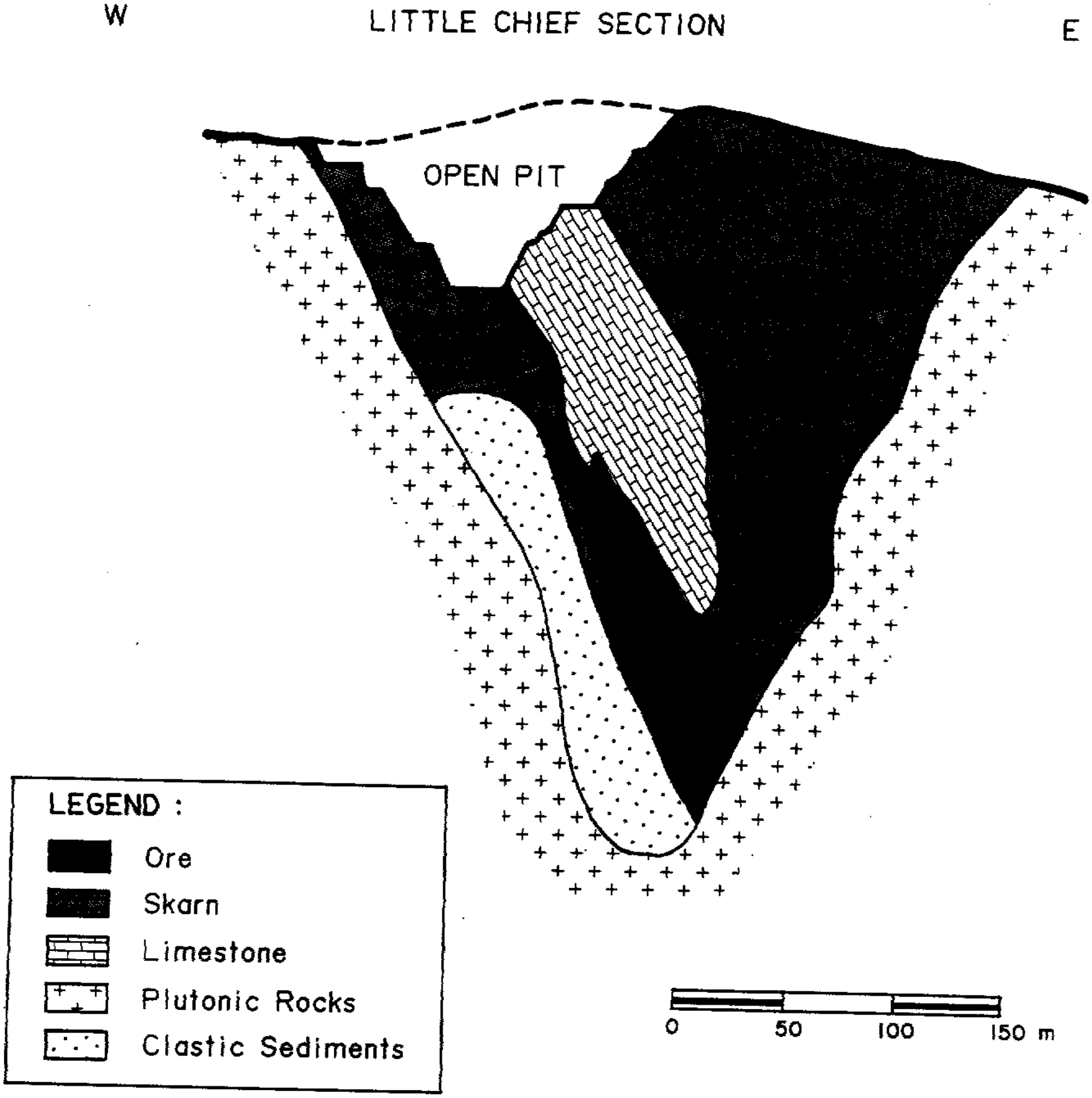

FIGURE 10: Schematic Cross-section of the Little Chief Pendant Showing Location of the Open Pit. (adapted from Tenney, 1981)

the smaller, richer deposits discouraged early miners. The simple, labour intensive methods of that time required a concentration on small high grade deposits in order to maximize profits.

With the advent of modern mechanized equipment capable of mining several hundreds of tonnes each day, the Little Chief orebody could be economically mined. In 1967 New Imperial Mines Ltd. began open pit mining on the Little Chief orebody and in two years removed 1,243,660 tons (1,128,000 tonnes) of ore grading 1.29% copper (Watson, 1984).

9. VALUE OF PRODUCTION

From 1900 until 1982 when the Little Chief Mine finally closed, a total of 10,130,000 tonnes was mined with an average grade of 1.5% copper. Approximately 177,000 oz of gold and 2,600,000 oz of silver were also extracted (Watson, 1984).

1)	151,950,000 kg @ $2.72/kg	= $	413,911,800
2)	177,000 oz of gold @ $396/oz	= $	70,092,000
3)	2,600,000 oz of silver @ $4.80/oz	= $	12,480,000
	TOTAL VALUE OF PRODUCTION 1993 CDN DOLLARS	= $	496,483,800

10. ECONOMIC FEASIBILITY

Activity on the Copper Belt and the profitability of the mining operations has been tied closely to the price of copper. Sharp drops in the copper price in 1907, 1920, and 1982 marked the closing of mines and along with the drop in 1929 halted exploration activity. Conversely increased copper prices have sparked renewed interest in the Copper Belt over the years. It is possible to follow the level of activity occurring on the Belt simply by charting copper prices over the years (See Appendix B).

Total outstanding reserves in deposits with greater than 100,000 tonnes of defined reserves as of 1984 are as follows:

Cowley Park	884,000 tonnes open pit/1.04% Cu
	668,000 tonnes underground/0.9% Cu
Keewenaw	202,000 tonnes open pit/1.0% Cu
Best Chance	447,000 tonnes open pit/0.71% Cu
Gem	625,000 tonnes open pit/1.0% Cu
Black Cub North	156,000 tonnes open pit/0.82% Cu
Total Reserves	2,982,000 tonnes averaging 1.0% Cu

(adapted from Watson, 1984)

Nearly 2.5 million tonnes of reserves lie in the Cowley Park, Keewenaw, Gem and Black Cub North deposits. These four deposits lie in the southern part of the belt within four kilometres of each other and their known reserves could be mined using open pit methods.

However, the low grade of these reserves, the lack of an existing milling infrastructure, and lack of any current exploration activity make it unlikely that there will be any mining activity on the Belt in the near future. Discovery of new reserves and/or a substantial increase in the price of copper would be necessary before consideration was given to further mining.

Hudson Bay Mining and Smelting Co. Ltd. still retains the majority of claims in the area but most are currently optioned to a smaller company. No exploration activity has occurred since 1990 and none is planned for the near future (Nolin, pers. comm.)

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APPENDIX A
GLOSSARY

ADIT: An opening driven horizontally into the side of a mountain or hill for providing access to a mineral deposit. An adit is open to the surface at one end, while a tunnel is open at both ends.

ANOMALY: Any departure from the norm which may indicate the presence of mineralization in the underlying bedrock. In geochemistry and geophysics, an area where the property being measured is significantly higher or lower than the larger surrounding area.

ASSAY: A chemical test performed on a sample of ores or minerals to determine the amount of valuable metals contained.

BALL MILL: A cylindrically shaped steel container filled with steel balls into which fine ore and water are fed. The ball mill is rotated, causing the balls to cascade, which in turn grinds the ore.

BEDDING: The arrangement of sedimentary rocks in layers.

BEDROCK: Solid rock forming the Earth's crust, frequently covered by soil or water.

BLASTHOLE: A hole drilled for purposes of blasting rather than for exploration or geological information.

CAGE: The conveyance used to transport men and equipment in a shaft.

CHUTE: An opening, usually constructed of timber and equipped with a gate, through which ore is fed from ore passes into mine cars.

CLASTIC SEDIMENTS: Rocks formed from particles (clasts) of other rocks that were mechanically transported and deposited by rivers.

COARSE ORE BIN: A large metal container which collects broken ore waiting to be fed into the crusher.

CONCENTRATE: A fine, powdery product of the milling process containing valuable metal and from which most of the waste material in the ore has been eliminated and discarded as tailings.

CONTACT: A geological term used to describe the line or plane along which two different rock types come together.

CORE: The long cylindrical piece of rock recovered by diamond drilling. The most common sizes of drill core are:

A - core diameter 27 mm
B - core diameter 36.5 mm
N - core diameter 47.6 mm
H - core diameter 63.5 mm

Core is usually removed from the diamond drill in 1.5 m sections.

CORE SAMPLE: A representative piece taken from the core for assay purposes. Usually accomplished by splitting the core in half along its long axis.

CROSSCUT: A horizontal opening driven from a drift at right angles to the strike of a vein or rock formation into the ore in preparation for stoping.

CROWN PILLAR: A block of solid ore or rock left in place between the stoping levels to structurally support the mined or stoped out orebody above. These pillars usually extend across the full length and width of the orebody, with the thickness or depth varying depending upon the strength of the rock making up the pillar.

CYCLONE CLASSIFIER: Large cylindrical container used to separate minerals according to their size and density. Coarser, heavier particles fall to the bottom of the cyclone and are returned to the rod or ball mill for further grinding.

DECLINE: A sloping underground opening, usually driven at a grade of about 15% to 20%, for machine access from level to level or from surface.

DEVELOPMENT: Underground work carried out for the purpose of opening up a mineral deposit. Includes shaft sinking, crosscutting, drifting and raising and all other owrk except mining ore.

DIAMOND DRILL: A rotary type of rock drill in which the cutting is done by abrasion rather than percussion. The cutting bit is set with diamonds and is attached to the end of long hollow rods through which water is pumped to the cutting face.

DILUTION: Waste of low-grade rock that is unavoidably removed along with the ore in the mining process, subsequently lowering the grade of the ore.

DIP: The angle at which a vein, structure or rock bed is inclined from the horizontal as measured at right angles to the strike.

DISSEMINATED ORE: Ore carrying small particles of valuable minerals, spread more or less uniformly through the rock; distinct from massive ore wherein the valuable minerals occur in almost solid form with very little waste material included.

DRAW POINT: Underground opening at the bottom of a stope, through which broken ore from the stope is extracted.

DRIFT: A horizontal underground opening that follows along the length of a vein or rock formation as opposed to a crosscut which crosses the rock formation.

DUMP: A pile or heap of broken rock or ore on surface.

EMBAYMENT: Bay or bay-like enclosure occurring along the contact between two rocks.

EROSION: The breaking down and subsequent removal of either rock or surface material by wind, wave action, freezing and thawing, or other processes.

EXPLORATION: Prospecting, sampling, mapping, diamond drilling and other work involved in searching for ore.

FACE: The end of a drift, crosscut or stope in which work is progressing.

FAULT: A break in the Earth's crust caused by tectonic forces which have moved the rock on one side with respect to the other; may extend for many kilometres or be only a few centimetres in length; similarly the movement or displacement may vary widely

FINE ORE BIN: A large covered structure which receives and stores crushed ore 2 cm or less in diameter. From here the ore is transported by conveyor into the mill for grinding.

FLOTATION: Milling process by which some mineral particles are induced to become attached to bubbles and float, and others sink. Used to concentrate valuable minerals and separate them from the waste rock.

FLOTATION CELLS: Part of the milling circuit consisting of a series of large tanks where flotation reagents, ore pulp, and air are mixed together in order to separate ore from waste rock.

FROTH: The mass of copper sulphide rich bubbles which float to the surface of flotation cells during the milling process.

GEOCHEMISTRY: The study of the chemical properties of rocks.

GEOPHYSICAL SURVEY: A scientific method of prospecting that measures the physical properties of rock formations. Common properties investigated include magnetism, specific gravity, electrical conductivity and radioactivity.

GLACIAL DRIFT: Sedimentary material, consisting of everything from clay to boulders, that has been transported by glaciers.

GLORY HOLE: An open pit from which ore is extracted, especially when broken ore is passed to underground workings before being hoisted.

GRINDING: Part of the milling circuit, where crushed ore is mixed with water in large revolving bins. It is further crushed and ground until it forms a fine pulp. Mills which contain steel balls or rods to assist the grinding process are called ball mills or rod mills respectively.

GRIZZLY: A grating, usually constructed of steel rails, placed over top of a chute or ore pass for the purpose of stopping large pieces of rock, or rock that may hang up in the pass.

HEAD GRADE: Original grade of ore going into the mill or concentrator.

HEADFRAME: A tall structure enclosing the top of the shaft and containing various hoisting equipment.

HEADING: The horizontal or level direction of a drift.

HIGH GRADE: Rich ore. As a verb, it refers to selective mining of the best ore in the deposit.

HOIST: Machine used for raising and lowering the cage or other conveyance in a shaft.

INDUCED POLARIZATION: Method of ground geophysical surveying that employs an electrical current to determine indications of mineralization.

IGNEOUS ROCKS: Rocks formed by the solidification of molten material that originated within the Earth.

INTRUSIVE: A body of igneous rock formed by the consolidation of magma intruded into other rocks, in contrast to lavas which are extruded upon the surface.

JAW CRUSHER: A machine in which rock is broken by the converging action of steel plates, consisting of a fixed vertical jaw or plate and a movable jaw oriented at a slight vertical angle. Ore enters at the top and is crushed by a series of rapid, forward movements similar to chewing. The plates converge at the bottom with a fixed size opening, so the size of the rock exiting is controlled.

LAGGING: Planks or small timbers placed between steel ribs along the roof of a stope or drift to prevent rocks from falling rather than to support the main weight of the overlying rocks.

LENS: Used to describe a body of ore that is thick in the middle and tapers towards the ends.

LEVEL: The horizontal openings on a working horizon in a mine. It is customary to work mines from a shaft, establishing levels at regular intervals, generally 50m or more apart.

LIMESTONE: A bedded, sedimentary deposit consisting chiefly of calcium carbonate. Most commonly formed from the skeletal remains of ocean life (i.e.:corals).

LOADING POCKET: Large metal bin located near the bottom of the shaft, having the same capacity as a skip. These bins are gradually filled with ore which is then dumped into the skip and taken to surface.

MAGMA: Molten material deep within the Earth, from which rocks are formed.

MAGNETOMETER: Instrument used to measure the magnetic attraction of underlying rocks.

MARGINAL DEPOSIT: An orebody of minimal profitability.

METALLURGY: The art or science of extracting metal or metals from ores.

METAMORPHIC ROCK: A rock whose original mineralogy, texture, or composition has been changed due to the effects of pressure, temperature or the gain or loss of chemical components.

MILL: A plant in which ore is treated for the recovery of valuable metals or concentration of valuable minerals into a smaller volume for shipping to a smelter or refinery.

MINE DRY: Building where miners shower and change working clothes.

MINERAL: A naturally occurring homogeneous substance having definite physical properties and chemical composition and if formed under favourable conditions, a definite crystal form.

MUCK: Ore or rock that has been broken by blasting.

MUCKING: The process of moving broken ore or rock after blasting.

MUCKING LEVEL: The main horizontal drift at the bottom level of a stope, where broken ore is loaded, hauled and dumped into ore passes.

NATIVE COPPER: Copper occurring in nature in pure form, uncombined with other elements.

OPEN PIT: A surface mine, open to daylight.

OPTION: An agreement between a property owner and a prospective buyer whereby the buyer has the exclusive right to evaluate the property prior to purchase of a previously agreed upon interest for a previously agreed upon price. Generally includes the requirement that the buyer spend money exploring the property prior to acquiring an interest

ORE: A mixture of ore minerals and waste from which at least one of the metals can be extracted at a profit.

OREBODY: A natural concentration of valuable material that can be extracted and sold at a profit.

ORE PASS: A vertical opening or raise where broken ore is dropped from the mucking level to an underground crusher or tramming level.

ORE RESERVES: The calculated tonnage and grade of mineralization which can be extracted profitably.

OUTCROP: An exposure of rock or mineral deposit that can be seen on surface, ie: not covered by overburden or water

OXIDATION: Chemical reaction caused by exposure to oxygen that results in a change in the chemical composition of the mineral.

PILLAR: A block of solid ore or rock left in place to structurally support the shaft, walls or roof in a mine.

PLUTON: Large body of igneous rock that solidified below the surfacr of the Earth.

PORTAL: The surface entrance to a tunnel or adit.

PULP: Pulverized or ground ore in solution

QUARTZ: Common rock-forming mineral consisting of silicon and oxygen (SiO_2).

RAISE: Vertical or inclined underground working that has been excavated from the bottom upward.

REAGENT: A chemical used in the flotation process that causes copper-bearing minerals to adhere to rising air bubbles, separating the concentrate from the tailing.

RECOVERY: Percentage of valuable metal in the ore that is recovered by the milling process.

ROCK: Any natural combination of minerals; part of the Earth's crust.

ROD MILL: A rotating steel cylinder that uses steel rods as a means of grinding ore.

ROOF PENDANT: An older body of rock which projects down from surface into a pluton. From plan view the sediments are completely surrounded by plutonic rocks.

SAMPLE: A small portion of rock or mineral deposit, taken so that the metal content can be determined by assaying.

SANDSTONE: Sedimentary rock consisting of grains of sand cemented together.

SCOOP TRAM: Rubber-tired, diesel-powered short front-end loader which loads, hauls and dumps broken ore from a drawpoint to an ore pass.

SEDIMENTARY ROCKS: Secondary rocks formed from material derived from other rocks or skeletal remains and laid down under water. Examples are limestone, shale and sandstone.

SHAFT: A vertical or inclined excavation in rock for the purpose of providing access to an orebody. Usually equipped with a hoist at the top which lowers and raises a conveyance for handling workers and materials.

SHALE: Sedimentary rock formed by the consolidation of mud or silt.

SHOTCRETE: A liquid cement mixture which is sprayed on the walls and roofs of level workings to prevent rocks from falling.

SILT: Muddy deposits of fine sediment usually found on the bottom of lakes.

SKARN: A term used to describe the metamorphic rocks surrounding an igneous intrusive where it comes in contact with a limestone or dolomite formation.

SKIP: A self-dumping bucket used in a shaft for hoisting rock or ore.

SLOT RAISES: A long vertical opening extending from the top to the bottom of the ore block which provides a void in which to blast the remainder of the ore in the stope.

SLURRY: A mixture of finely ground rock and water that can be pumped.

SLUSHER: A cable winch mechanism which activates a scraper which scrapes broken ore into a nearby ore pass.

STATION: An enlargement of a shaft made for storage and handling of equipment and for driving drifts at that level.

STOCKPILE: Broken ore heaped on surface, pending treatment or shipment.

STOPE: An excavation in a mine from which ore is being or has been extracted.

STRIKE: The direction, or bearing, from true north of a vein or rock formation measured on a horizontal surface.

STRIP: To remove the overburden or waste rock overlying an orebody in preparation for mining by open pit methods.

STRIPPING RATIO: The ratio of tonnes removed as waste relative to tonnes of ore removed from an open pit mine.

SUBLEVEL: A level or working horizon in a mine between main working levels.

SUB-LEVEL OPEN STOPING: Common method of underground mining where large stopes (blocks of ore) are drilled and blasted from different levels. Broken ore falls to the bottom level of the stope where it is mucked and hauled away.

TAILINGS: Material rejected from a mill after most of the recoverable valuable minerals have been extracted.

TAILINGS POND: A low-lying depression used to confine tailings.

THICKENER: A large, round tank used in milling operations to separate solids from liquids; clear fluid overflows from the tank and rock particles sink to the bottom.

TIMBERING: Reinforcing the walls of a shaft, adit, drift or crosscut using wooden timbers.

TRACK DRIFT: A drift which is driven using rail line equipment. The completed drift is used to facilitate hauling ore with mine cars.

TRACKLESS: Mining equipment that moves by means other than rail. An example would be rubber-tired scoop trams.

TRAMMING LEVEL: The drift in which ore is loaded into mine cars and is hauled to a centralized crushing or hoisting facility.

TUNNEL: A horizontal underground opening, open to the atmosphere at both ends.

VEIN: A fissure, fault or crack in a rock filled by minerals that have travelled upwards from some deep source.

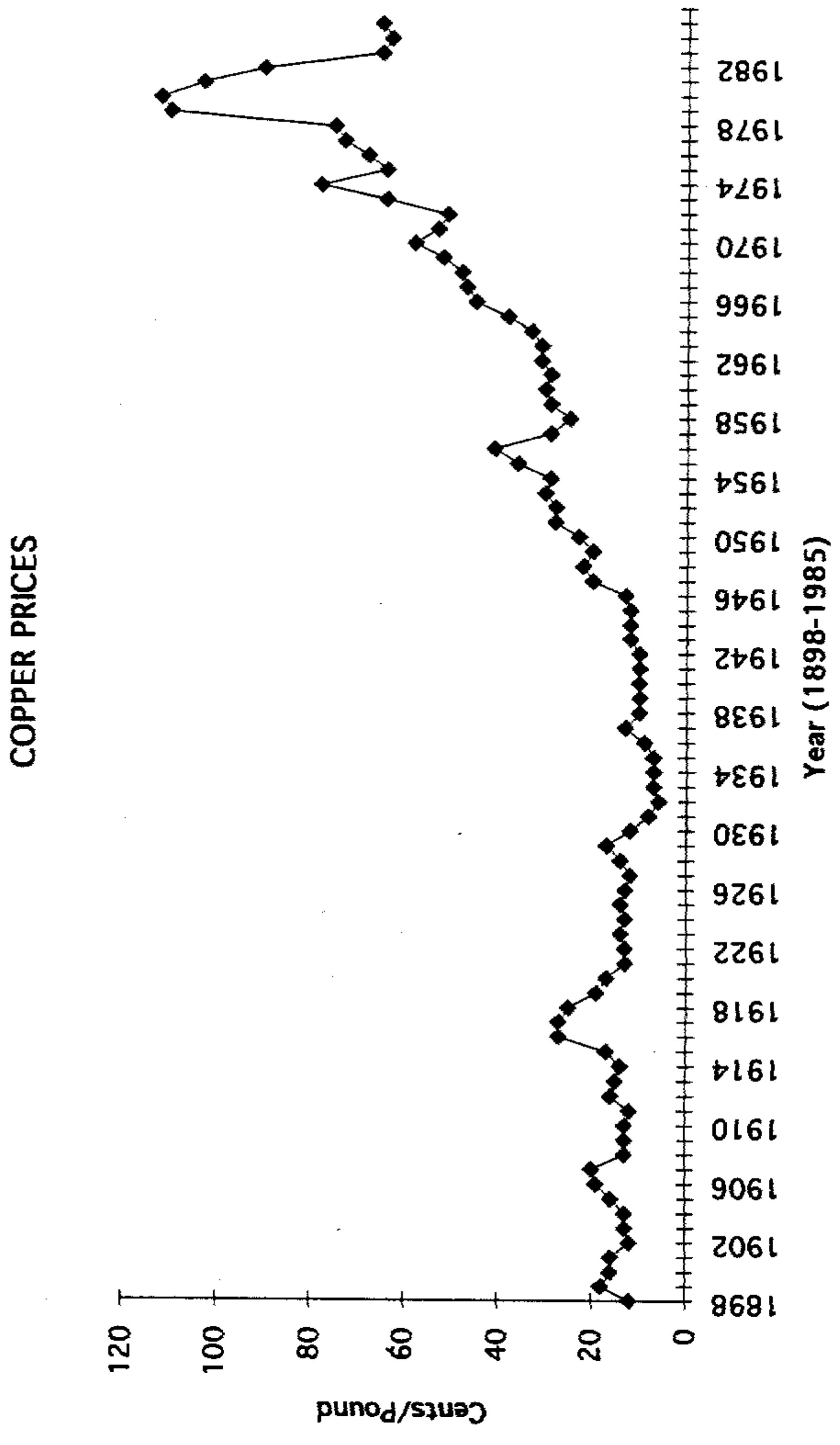
VOLCANIC ROCKS: Igneous rocks formed from magma that has flowed out or has been violently ejected onto the Earth's surface.

WALL ROCKS: Rock units on either side of an orebody. The hangingwall and footwall rocks of an orebody.

WASTE: Mineralized or unmineralized rock that is not ore.

WINZE: An internal shaft, offset from the main shaft to surface.

APPENDIX B



Graph showing average annual copper prices during the productive years of the Whitehorse Copper Belt.
(Source: Statistics Canada)